UNITED STATES AIR FORCE RESEARCH LABORATORY

Point of Maintenance Ruggedized Operational Device Evaluation and Observation Test Report

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FOR THE COMMANDER

Mark M. Hoffman

MARK M. HOFFMAN
Deputy Chief
Deployment and Sustainment Division
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13. ABSTRACT *(Maximum 200 words)*
The Air Force Directorate of Maintenance (USAF/ILM) and the Standard Systems Group, Maintenance Systems Division (HQ SSG/ILM) sponsored an evaluation test for the purpose of identifying potential electronic tools for use at the flightline point of maintenance. The Air Force Research Laboratory, Logistics Readiness Branch (AFRL/HESR) and the University of Dayton Research Institute (UDRI) were commissioned by SSG/ILM to independently and objectively perform the evaluation. The evaluation was conducted at the 57th AGS, Nellis AFB, Nevada, 20-22 August 2002. The Ruggedized Operational Device Evaluation and Observation (RODEO) test examined hardware packaging, software user interface, and environmental factors associated with the usability of potential Point of Maintenance (POMx) electronic tools (E-Tools). The test evaluated the usability of 11 potential e-tools for use in an Air Force flightline environment. The evaluation compared the platforms for maintenance documentation (e.g., opening work orders) from the aircraft location. The eleven devices consisted of: 1) five notebook computers, 2) two handheld computers, 3) two palm computers, and 4) two alternative computer types (a slate computer and a hybrid handheld/notebook). Air Force personnel used each device in a flightline-type setting to simulate opening work orders. They were required to try each device with and without chemical gloves and masks. This report documents the findings of the evaluations, based on analysis of participant comments, ratings, and rankings.

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1 Executive Summary

The Air Force Directorate of Maintenance (USAF/ILM) and the Standard Systems Group, Maintenance Systems Division (HQ SSG/ILM) sponsored an evaluation of eleven potential electronic devices or "E-Tools" for flightline use. The purpose of this E-Tool Ruggedized Operational Device Evaluation and Observation (RODEO) was to examine hardware packaging, software user interface, and environmental factors associated with the usability of several potential Point of Maintenance (POMx) E-Tools for maintenance data collection on the flightline. Air Force Research Laboratory, Logistics Readiness Branch (AFRL/HESR) and the University of Dayton Research Institute (UDRI) were commissioned by SSG/ILM to independently and objectively perform the evaluation. The evaluation was conducted at the 57th AGS, Nellis AFB, Nevada, 20-22 August 2002.

This evaluation employed standard usability data collection techniques aimed at identifying both potential usability problems and actual problems with each of the devices. Twelve U.S. Air Force personnel participated in the study. One day was devoted to test preparation prior to the initiation of the actual test. Testing occurred over a two-day period, with six participants on the first day and six on the second day. Participants were in-briefed, given chemical gear (masks and gloves), and then proceeded to the flightline where they performed a series of actions resembling actual maintenance data collection activities. Each participant was given the opportunity to use all eleven devices. Throughout the test, participants were asked for verbal feedback. After using each device, participants were asked to complete a questionnaire that included rating scales for various characteristics. After using all devices in a given category, participants rank ordered the devices in the group along certain dimensions. Experimenters recorded observations (through note taking and video tapes) throughout the study.

The purpose of this study was to provide a subjective judgment, based on standard usability testing methods, as to the hardware usability of various mobile devices on the flightline. Based on analysis of participant comments, ratings and rankings, the devices can be categorized according to the following rating categories:

1. *Usable as designed.* Comments, ratings and rankings revealed no problems or potential problems.
2. *Usable as currently designed, but with considerations for future designs.* Comments, ratings and rankings revealed only potential problems.
3. *Not usable as currently designed.* Comments, ratings and rankings revealed one or more actual problems with the device on the flightline.

Using information collected in the study, each device has been assigned an appropriate rating as shown in the following matrix (Table I):

Table I. Devices Used in E-Tool RODEO and Resulting Ratings

A. Laptop Devices:	Rating
Dolch Computer System	2
EDNA	3
ITRONIX GoBook	2
Panasonic Toughbook 28	2

Paravant Scorpion	2
B. Handheld Devices:	**Rating**
Dolphin 7400	2
Intermec 700	2
C. Palm Devices:	**Rating**
Palm 515	2
Symbol Palm	1
D. Alternative Devices:	**Rating**
LXE	3
Xplorer	2

In summary, 9 of the 11 devices evaluated are suitable for maintenance data collection activities on the flightline. The two devices not recommended for use in their current state (i.e., Category 3) are the EDNA and the LXE. The EDNA had many complex usability problems such as screen readability and keyboard design. The LXE could be made suitable for flightline use if usability issues associated with the screen readability can be resolved.

For those devices rated in Category 2, several areas for potential improvement in future design considerations were identified during testing. Some of these considerations include:

a. Touch screens should be available on the computing device, where possible.
b. Multiple means of entering text should be available on each device (e.g., hard keyboard, onscreen keyboard, handwriting recognition). Where hard keyboards are provided, they should be of standard QWERTY type.
c. Screen visibility must be improved for various lighting conditions on certain identified devices.

An informal heat and sunlight exposure test was also conducted, see Appendix C.

2 Introduction

This document describes the usability test conducted by the Air Force Research Laboratory and the University of Dayton Research Institute to examine hardware packaging, software user interface and environmental factors associated with the usability of potential Point of Maintenance (POMx) electronic tools (E-Tools). The Air Force Directorate of Maintenance (USAF/ILM) and the Standard Systems Group, Maintenance Systems Division (HQ SSG/ILM) sponsored and coordinated this usability test for the purpose of identifying potential e-tools for use at the point of maintenance. E-tools identified as usable will be included on the E-Tools Matrix—a website which will identify e-tools suitable for U.S. Air Force maintenance use.

The Usability Test evaluated the usability of 11 potential e-tools for use in an Air Force flightline environment. The purpose of the evaluation was to compare the platforms for maintenance documentation (e.g., opening work orders) from the aircraft location. The eleven devices consisted of: 1) five notebook computers, 2) two handheld computers, 3) two palm computers, and 4) two alternative types (a slate computer and a hybrid handheld/notebook). U.S. Air Force personnel used each device in a flightline-type setting to simulate opening work orders. They were required to try each device with and without chemical gloves and masks.

2.1 Objectives

This usability test was designed to address the following usability issues:

- Hardware packaging that deals with display size.
- Hardware packaging that deals with device size.
- Hardware packaging that deals with apparent ruggedization (perceived ruggedization as opposed to tested ruggedization).
- Hardware packaging that deals with keyboard layout.
- Hardware packaging that deals with pointing devices. *
- Software user interface that deals with navigation.
- Software user interface that deals with data entry. *
- Software user interface that deals with drop down menus.
- Environmental factors that deal with sunlight readability. *
- Environmental factors that deal with perceived portability. *
- Environmental factors that deal with wearing chemical resistant gear (specific issues addressed for chemical gear are noted above with asterisks (*)).

2.2 Test Methodology

Usability test methods used for the current evaluation are based on principles outlined by Dumas and Redish (1993). In accordance with usability testing methods outlined by Dumas & Redish, design of the study included three steps (see Figure 1). First, the major usability issues were identified. These included concerns about the general hardware use (input devices, size, and ruggedization), software use (data entry, and GUI features), and environmental influences (sunlight, portability, and use with chemical gear). From these general concerns, specific concerns were identified (see the objectives above). Finally, methods for collecting information relevant to these concerns were identified. Methods included multiple metrics for each concern.
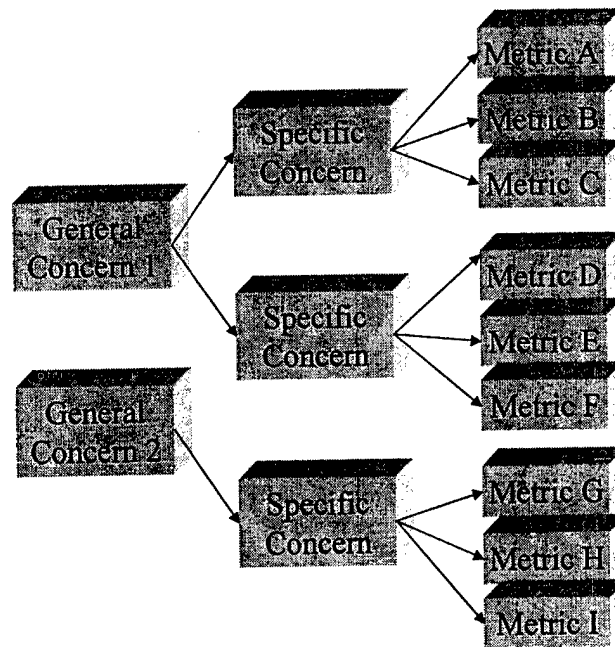
Figure 1. Usability testing methods (Dumas and Redish, 1993)

Using this method, once the data is collected, data analysis leverages the strength of triangulating information gathered for each specific concern. For example, the specific concern dealing with display size included use of three metrics: subject ratings of the acceptability of the screen size, experimenter observations of the participant while using the device, and specific participant comments concerning the size of the display (both written and verbalized, during the test and in post-test discussions). Using triangulation, each metric is used to confirm findings of another metric so that if all three metrics identify the same issue, the strength of usability concern is increased. Similarly, as multiple participants identify the same usability problem, the usability problem is revealed. Methods used to analyze results are fully addressed in the Results section of this document.

In identifying usability concerns, research indicates that the number of participants need not be as high as tests aimed at determining significance (e.g., ANOVAs, or tests of correlation). Virzi (1992) identifies that 4 to 5 subjects identify 80% of the usability problems with a system, and that additional subjects are less likely to identify any new problems. The current test included 12 subjects, and therefore should be considered to be of relatively high strength in identifying usability concerns for the devices tested.

3 Method

3.1 Participants and Facility

Twelve U.S. Air Force personnel at Nellis AFB served as subjects. These individuals were assigned to the 57th Aircraft Generation Squadron (AGS), the 99th Communications Squadron (CS), the 57th Equipment Maintenance Squadron (EMS), and the 66th Rescue Squadron (RQS). Their career backgrounds included both aircraft maintenance and communications electronics maintenance experience. Testing was conducted at the 57th AGS, Nellis AFB, NV.

3.2 Time and Schedule

Pre-testing occurred on the first day of testing, August 20. Pre-testing consisted of assuring that appropriate software was loaded on all hardware devices. Additionally, scenarios were all re-evaluated to assure that the same types of manipulations were required across devices. Testing was conducted on August 21 & 22. Six subjects participated on the first day, and another six subjects participated on the second day, for a total of 12 subjects. Scheduling was arranged based solely on availability, so as not to interfere with subjects' regular work. Testing on both days lasted for most of the day (morning and afternoon).

3.3 Test Equipment Requirements

Hardware used in the test included the items listed below.

1. Dolch Computer System, spare battery, charger.
2. EDNA computer.
3. Itronix GoBook series, spare battery, and charger.
4. Panasonic Toughbook 28 series with option of 192M RAM, spare battery, and charger.
5. Paravant rugged portable computer, spare battery, charger.
6. Dolphin 7400 mobile computer, spare battery, and charger.
7. Intermec 710, spare battery, and charger.
8. Palm 515, and charger.
9. Symbol palm, and charger.
10. LXE computer, spare battery, and charger.
11. Xplorer slate computer, spare battery, and charger.

3.4 Data Collection Equipment

Data collection instruments included the following items.

1. One (1) video tape recorder with batteries.
2. Blank videocassette tapes (14).
3. Clipboards (12).
4. Package of pens (1).
5. Digital Camera (1).
6. Notebook computer for subject surveying (1).
7. Digital thermometer.
8. Antiseptic wipes to assist in cleaning chemical gear.
9. Chemical Gloves and Masks (6 sets), provided by Nellis AFB. Masks were cleaned at the end of each day and glove inserts were washed overnight for sanitation purposes.

3.5 Data Collection Packet

Data collection packets included a variety of forms. Each subject was given a complete packet at the beginning of the test and completed all forms prior to the end of the test.

1. In-briefing (see Attachment 2)
2. Consent form (see Attachment 2)
3. Pre-test questionnaire (see Attachment 2)
4. Post condition questionnaires for each hardware device (see Attachment 2)
5. Post-test questionnaire (see Attachment 2)

3.6 Data Collection Team

The data collection team consisted of five individuals: 1) four experimenters, and 2) a study coordinator. The experimenters provided the majority of the interaction with test participants. The study coordinator was responsible for assuring that scheduling was completed for all participants, that all hardware and software were available for the test, and that in-briefing and out-briefing sessions were conducted for each participant.

3.7 Pre-Test Requirements

Several activities needed to be completed prior to beginning this test; most of these activities required coordination with the hosting facility or with the vendors supplying the hardware to be used in the test. Standard Systems Group, Maintenance Systems Division (HQ SSG/ILM) assisted with many of these pre-test needs.

Section 1:

1. Six chemical resistant gloves and masks were required for the test, including varying sizes of large, medium and small.
2. Experimenters required at least a half-day of viewing the CAMS GUI. This was accomplished during the first day, pre-testing.
3. Experimenters required time to view the POMx software. This software was loaded on the handheld devices and experimenters reviewed the software with system developers several weeks prior to the test.
4. Experimenters required time to review the features of each device so that they would be familiar with each device prior to the test. This was accomplished during the first day, pre-testing.
5. A list of final hardware to be tested was required so that hardware representatives could be present for the test. This was accomplished during the first day, pre-testing.
6. Experimenters created and finalized scenarios for the subjects to use during the test. Scenarios were developed several weeks prior to the test and finalized on the first day, pre-testing.
7. The devices were loaded with the correct software. POMx software was loaded on every handheld prior to the testing period. The CAMS GUI, or equivalent, interface was loaded on all other devices during the first day, pre-testing.
8. Clearance was granted for experimenters to take photos at Nellis AFB. Videotaping and digital photos were captured during the test.
9. The test was held outside and tables were required for the devices. The tables served as stations. A total of five tables were needed. Electrical power was also required for charging batteries and electrical connection.

10. Arrangements for an indoor locked room were made so that equipment could be locked in overnight.

3.8 Test Procedure

Test participants were provided an in-briefing in a conference room setting. The in-briefing provided an overview of the purpose of the test. At this time they also selected the chemical gear they would be using for the test, completed the consent form, and completed the pre-test questionnaire. Each participant was given a clipboard that contained all questionnaires to be completed in the test. These forms were ordered in the sequence in which participants were to interact with the devices (see Table II). The order was counterbalanced across participants to address any possible order effects.

Table II. Subject Matrix

Subject	First Station	Second Station	Third Station	Fourth Station
Subject 1	Panasonic Toughbook	Dolphin 7400	LXE	Symbol Palm
	Paravant Scorpion	Intermec 700	Xplorer	Palm 515
	ITRONIX GoBook			
	Dolch Computer System			
	EDNA Computer			
Subject 2	Paravant Scorpion	Intermec 700	Xplorer	Palm 515
	ITRONIX GoBook	Dolphin 7400	LXE	Symbol Palm
	Dolch Computer System			
	EDNA Computer			
	Panasonic Toughbook			
Subject 3	ITRONIX GoBook	Dolphin 7400	LXE	Symbol Palm
	Dolch Computer System	Intermec 700	Xplorer	Palm 515
	EDNA Computer			
	Panasonic Toughbook			
	Paravant Scorpion			

Subject	First Station	Second Station	Third Station	Fourth Station
Subject 4	Intermec 700	LXE	Palm 515	Dolch Computer System
	Dolphin 7400	Xplorer	Symbol Palm	EDNA Computer
				Panasonic Toughbook
				Paravant Scorpion
				ITRONIX GoBook
Subject 5	Dolphin 7400	Xplorer	Symbol Palm	EDNA Computer
	Intermec 700	LXE	Palm 515	Panasonic Toughbook
				Paravant Scorpion
				ITRONIX GoBook
				Dolch Computer System
Subject 6	Intermec 700	LXE	Palm 515	Dolch Computer System
	Dolphin 7400	Xplorer	Symbol Palm	EDNA Computer
				Panasonic Toughbook
				Paravant Scorpion
				ITRONIX GoBook
Subject 7	Xplorer	Symbol Palm	Panasonic Toughbook	Dolphin 7400
	LXE	Palm 515	Paravant Scorpion	Intermec 700
			ITRONIX GoBook	
			Dolch Computer System	
			EDNA Computer	

Subject	First Station	Second Station	Third Station	Fourth Station
Subject 8	LXE	Palm 515	Paravant Scorpion	Intermec 700
	Xplorer	Symbol Palm	ITRONIX GoBook	Dolphin 7400
			Dolch Computer System	
			EDNA Computer	
			Panasonic Toughbook	
Subject 9	Xplorer	Symbol Palm	ITRONIX GoBook	Dolphin 7400
	LXE	Palm 515	Dolch Computer System	Intermec 700
			EDNA Computer	
			Panasonic Toughbook	
			Paravant Scorpion	
Subject 10	Palm 515	Dolch Computer System	Intermec 700	Xplorer
	Symbol Palm	EDNA Computer	Dolphin 7400	LXE
		Panasonic Toughbook		
		Paravant Scorpion		
		ITRONIX GoBook		
Subject 11	Symbol Palm	EDNA Computer	Dolphin 7400	LXE
	Palm 515	Panasonic Toughbook	Intermec 700	Xplorer
		Paravant Scorpion		
		ITRONIX GoBook		
		Dolch Computer System		

Subject	First Station	Second Station	Third Station	Fourth Station
Subject 12	Palm 515	Paravant Scorpion	Intermec 700	Xplorer
	Symbol Palm	ITRONIX GoBook	Dolphin 7400	LXE
		Dolch Computer System		
		EDNA Computer		
		Panasonic Toughbook		

Four tables were arranged in the shade next to the flightline. The first table had the five notebook computers, the second table had the two handheld computers, the third table had the two palm computers, and the fourth table had the alternative devices (the slate and hybrid handheld notebook). One experimenter was permanently stationed at each table.

Participants went to the appropriate table (according to the assigned sequence). General training was provided so that basic functions were learned as necessary for the devices. Each participant started by taking the first device on his list into the sunlight and performing a sample maintenance open work order task. Participants were permitted to repeat the task if desired; no time or error data were collected on these tasks. Once they completed the task, they were asked to fill out a post-condition questionnaire (see Attachment 2). At this point participants proceeded to the next device in their sequence and repeated the process. After having used all devices on the table, participants were asked to complete a post-test questionnaire asking for rank order preferences on all of the devices at that table (see Attachment 2).

Following this process, participants were asked to don their chemical gear and repeat selected portions of the process with the gear on (e.g., use each device in the sunlight). Having completed this, participants again completed a questionnaire on each device, and provided rank orders for the devices. After completing the chemical gear portion of the test at each table, participants proceeded to the next table and began the process again.

4   Results

Analysis of the data collected during this study included evaluations of each device, with and without the use of chemical gear, and relative ranking of devices within a station along a series of items. These analyses are detailed in the following sections. It is important to note that a triangulation method was used in the analysis of findings for each device. Triangulation was implemented as defined in the following paragraphs.

Ratings for each device were gathered for each item in the questionnaire (e.g., for each question), and mean ratings and standard deviations were then calculated on each item for that device. Ratings could range from 1 to 5 (one was positive and five was negative).

A priori, criteria were set that 1) any item with an average rating of ≥ 3 indicated a usability problem, and 2) any item where the total of the average rating plus standard deviation was ≥ 3 indicated a potential usability problem.

Once this initial analysis was complete, user ratings were plotted on a cluster graph for items that indicated usability problems or potential usability problems. User comments and observer notes were then analyzed and collapsed to assist in the definition and clarification of the problem or potential problem. That is, user comments and observer notes that related specifically to the item were added to the analysis to assist in further definition of the problem or potential problem.

For each usability concern (e.g., readability in sunlight, use of pointing device) users were asked to rank order their preferences across devices. Rankings were then analyzed to further validate the rating data. If the device had usability problems or potential problems and was ranked lower than the other devices (less preferred) this further substantiated that the device had usability issues associated with it.

4.1   Laptop Devices

4.1.1   Dolch Computer System

The Dolch laptop computer has a standard QWERTY keyboard. The input device is a keyboard touchpad with two-button control. It does not have a touch screen.

4.1.1.1 Without Chemical Gear

The mean and standard deviations for user responses to the acceptability ratings for the Dolch laptop in the non-chemical gear condition are included in Figure 2. No means or standard deviations were in the unacceptable range.

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Laptop Computers – Dolch

	Completely Acceptable	Reasonably Acceptable	Borderline	Moderately Unacceptable	Extremely Unacceptable
Display Size	▲				
Computer Size	▲				
Apparent Ruggedization	▲				
Layout	▲				
Pointing Device	▲				
Navigating	▲				
Entering Data	▲				
Drop Down Menus	▲				
Reading Data	▲				
Perceived Portability	▲				
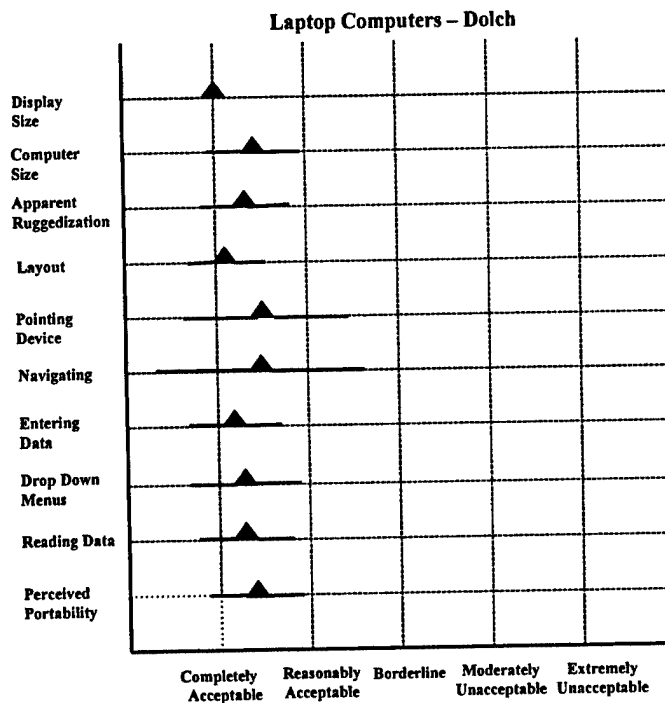
<u>Figure 2.</u> Means and Deviations – Dolch Laptop Computer

When users were not wearing chemical gear, no problems or potential problems for the Dolch laptop computer were revealed through user rankings.

Five participants listed the laptop keyboard as their favorite feature of the Dolch, indicating that the "keyboard keys (were) extremely easy to use, not cumbersome." The apparent ruggedization of the computer also drew positive comments from four participants. Two subjects also mentioned that the system had good visibility in sunlight.

Two subjects submitted comments indicating a desire for a touch screen. Two other constructive comments indicated that the system was slightly larger than desired – "not as compact as I would like" – and that it was heavy.

4.1.1.2 With Chemical Gear

The means and standard deviations for user responses to the acceptability ratings for the Dolch laptop in the chemical gear condition are included in Figure 3. None of the means were in the unacceptable range. However, the standard deviation of the user ratings of the pointing device in the chemical gear condition indicated a potential problem.

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Laptop Computers – Dolch with Chemical Gear

	Completely Acceptable	Reasonably Acceptable	Borderline	Moderately Unacceptable	Extremely Unacceptable
Pointing Device					
Entering Data					
Reading Data					
Perceived Portability					
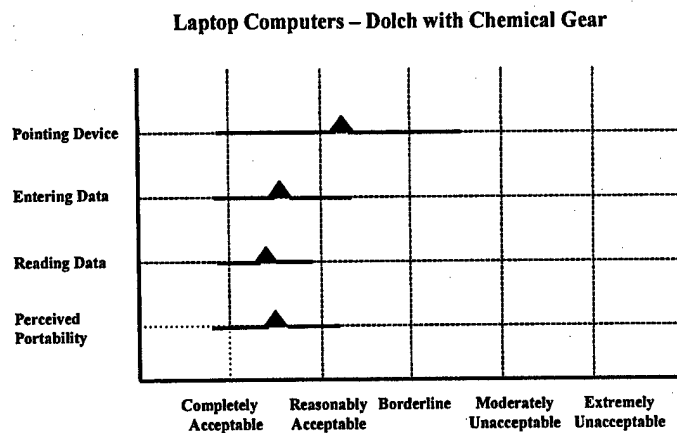
Figure 3. Means and Deviations – Dolch Laptop Computer with Chemical Gear

Laptop Devices
Dolch with Chemical Gear

Pointing Device (N=14)

Potential problem using pointing device with the Dolch while wearing Chem Gear

Completely Acceptable   Reasonably Acceptable   Borderline   Moderately Unacceptable   Extremely Unacceptable
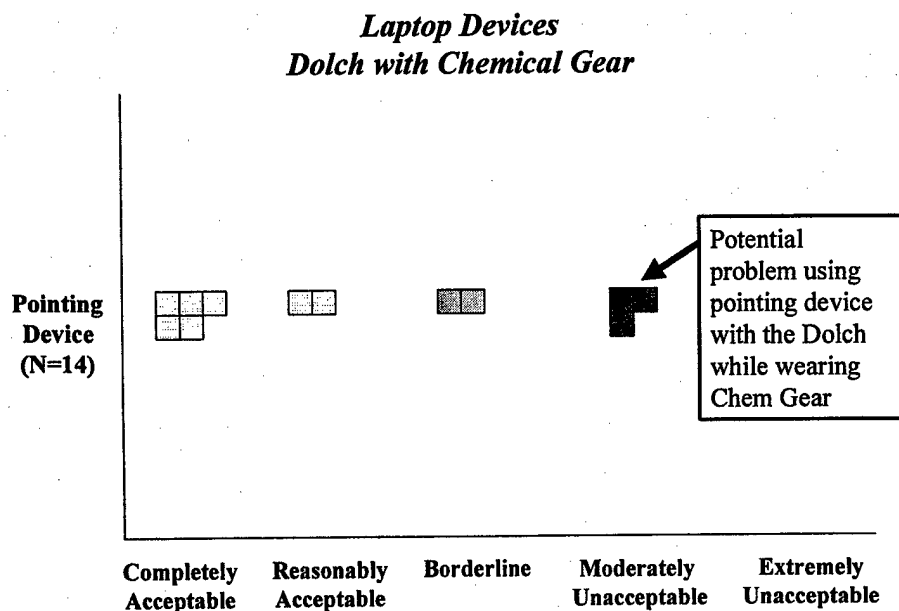
Figure 4. Individual Ratings for Dolch Laptop Computer with Chemical Gear

Participant ratings of the Dolch computer indicated a potential problem using the pointing device when wearing chemical gear. While seven individuals rated the device in the acceptable

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range for this category, two participants rated the device as "Borderline," and three participants rated the access of the Dolch using the pointing device as "Moderately Unacceptable" (Figure 4).

While one participant noted that the "mouse was very easy to navigate with, very light," five users noted some difficulty using the mouse/mouse touchpad. The touchpad and mouse were listed three times when subjects were asked to classify their least favorite feature (but another subject listed the touchpad as his favorite feature on the device). Other comments indicated that the touchpad "almost didn't work" and sometimes failed to take inputs, that the pointing device was difficult to use/move with gloves, and that a touch screen was a necessity for a laptop when one was wearing chemical gear.

Other positive comments relevant to use of the Dolch laptop computer while wearing chemical gear indicate that two users perceived the system and screen as "nice and rugged," and two participants liked the display and found it easy to read. Also, two participants provided positive comments about the laptop keypad keys, as the keyboard was quite "functional," and the keys were "easy to get to with gloves." Two subjects rated the keyboard as their most favorite feature on the Dolch laptop computer.

Other constructive comments indicated that, for two users in particular, the screen might have faded a bit in the sun.

4.1.2 EDNA

The EDNA laptop computer has a standard QWERTY keyboard. The input device is a button-like joystick mouse. It does not have a touch screen.

The results for EDNA indicate that only ten respondents (n=10) were able to provide feedback on this device. During the first day of the study, connectivity issues on the device prevented two participants from completing the designed task, which involved interacting with a CAMS data collection form. As they did not complete a relevant task with the EDNA, these two individuals were unable to provide feedback on the device. Subsequent users were provided with a CAMS-like interface as they interacted with the EDNA. The feedback from these users is reflected below.

4.1.2.1 Without Chemical Gear

The means and standard deviations of user responses to the EDNA in the non-chemical gear condition are presented in Figure 5. Problems with computer size, reading data, and perceived portability are highlighted by means in the unacceptable range. An additional six categories yielded standard deviations in the unacceptable range. These indicate that the display size, layout, pointing device, entering data, navigating and drop down menus on the EDNA are potential problems.

Laptop Computers – EDNA

	Completely Acceptable	Reasonably Acceptable	Borderline	Moderately Unacceptable	Extremely Unacceptable

Display Size

Computer Size

Apparent Ruggedization

Layout

Pointing Device

Navigating

Entering Data

Drop Down Menus

Reading Data

Perceived Portability

Completely Acceptable   Reasonably Acceptable   Borderline   Moderately Unacceptable   Extremely Unacceptable

Figure 5. Means and Deviations – EDNA Laptop Computer
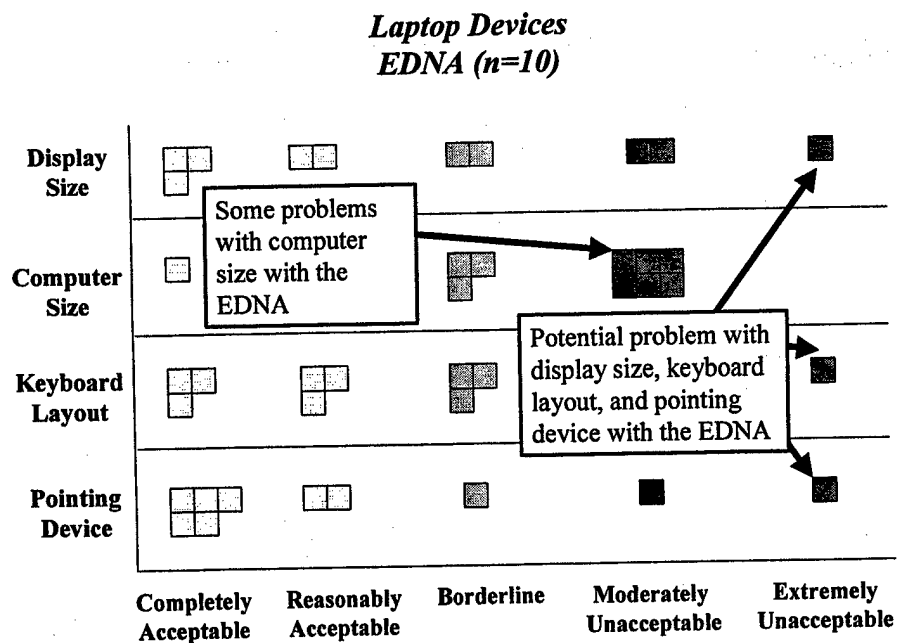
Laptop Devices
EDNA (n=10)

Display Size

Computer Size

Some problems with computer size with the EDNA

Keyboard Layout

Potential problem with display size, keyboard layout, and pointing device with the EDNA

Pointing Device

Completely Acceptable   Reasonably Acceptable   Borderline   Moderately Unacceptable   Extremely Unacceptable

Figure 6. Individual Ratings for EDNA Laptop Computer

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Laptop Devices
EDNA (n=10) Continued
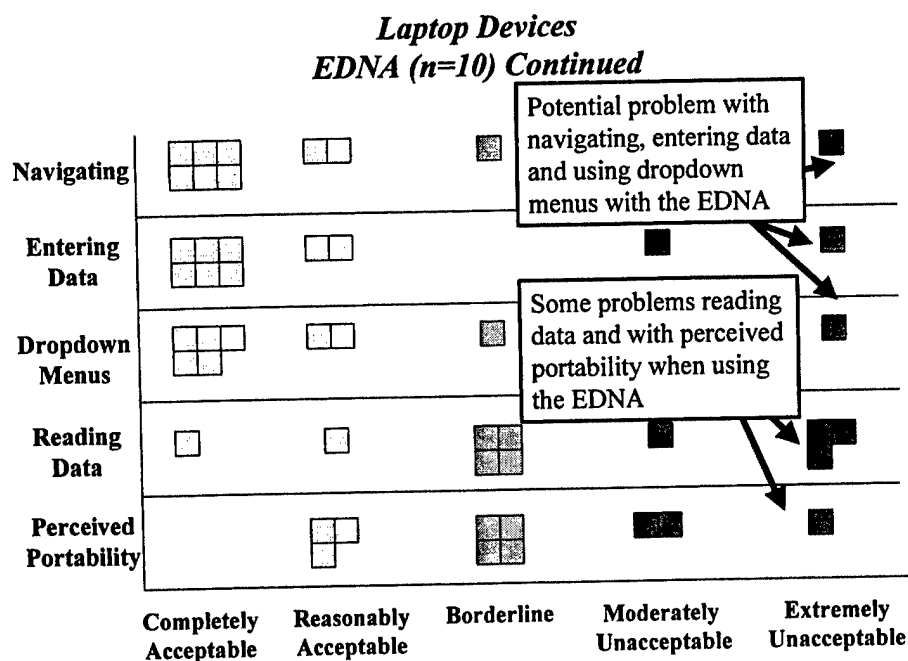
Figure 6. Individual Ratings for EDNA Laptop Computer (continued)

Individual participant responses during the non-chemical gear condition identified problems with the computer size, reading data, and perceived portability of the EDNA laptop, and revealed potential for problems with the display size, keyboard layout, pointing device, navigating, entering data, and using the drop down menus on the EDNA laptop (Figure 6).

As several of these problems and potential problems may be related to one another, they will be addressed in the most relevant pairings. For example, participant responses indicated problems with computer size and perceived portability. In the Computer Size category on the EDNA, only one response was in the acceptable range. Three participants rated this aspect of the EDNA as "Borderline," while six participants rated the computer size of the EDNA as "Moderately Unacceptable." Comparatively, three responses were in the acceptable range for the Perceived Portability category. Four participants rated this aspect of EDNA as "Borderline," two rated it "Moderately Unacceptable" and one rated it "Extremely Unacceptable." Participants overwhelmingly remarked that the EDNA was too heavy or too bulky, with eight of ten subjects providing negative comments about the size and weight of the device. It was "not portable, too heavy," "heavy and bulky, won't fit in most toolboxes," "way too bulky in size," and simply, "too big." Thus, the computer size – classified as "too bulky" by several participants – would have negatively impacted perceived portability. Furthermore, two participants expressed other portability concerns, pointing out that the power cord was difficult to work with and specifying that they did not like "having to maintain a (power) connection." The EDNA is not battery powered.

While the size and weight of the EDNA negatively impacted participant responses in the Computer Size and Perceived Portability categories, these elements also may have impacted the strong indication that the EDNA was perceived as quite rugged. Favorite features of the device

were "the ruggedness" (in two responses), that it was "very tough," and that "it can actually withstand some pounding!"

Keyboard layout, entering data, navigation, use of drop down menus, and ease of using the pointing device were revealed as potential problems based upon participant responses. In the Keyboard Layout category, six participants rated the EDNA in the acceptable range; three participants rated it as "Borderline," and one participant rated the device as "Extremely Unacceptable." Eight participants rated entering data in the acceptable range, with six individuals rating entering data on the EDNA as "Completely Acceptable." One participant rated entering data on the EDNA "Moderately Unacceptable," and one participant rated this "Extremely Unacceptable." While two participants provided positive remarks about the keyboard, listing the "waterproof keyboard" and "good keyboard" as a favorite feature of the device, three individuals listed this as the least desirable feature of the EDNA, indicating that the "keypad was too tight (you really have to press hard)." This difficulty with the keyboard may have been one facet of the somewhat negative ratings individuals provided regarding entering data on the EDNA.

Seven participants rated the ease of using the pointing device in the acceptable range, with five of those ratings specifying that the EDNA was "Completely Acceptable" in this category. One participant rated the ease of using the pointing device on the EDNA as "Borderline," one participant rated it as "Moderately Unacceptable," and one participant rated it as "Extremely Unacceptable." Navigation, an extension of the use of the pointing device, is a potential problem, as well. Eight participants rated navigation on the EDNA in the acceptable range. One individual provided a rating of "Borderline," and one individual provided a rating of "Extremely Unacceptable" for the category of navigation on the EDNA. For use of drop down menus on the EDNA, seven participants provided ratings in the acceptable range. One participant provided a rating of "Borderline," and one participant provided a rating of "Extremely Unacceptable." One participant did not provide a rating for drop down menus on the EDNA in this condition. Only two participants provided comments corroborating the potential problems specific to navigational (i.e., pointing device, navigation, and drop down menus) issues. One individual listed the mouse adaptor as his least favorite feature of the device; another individual commented that the device was, simply, "difficult to maneuver."

Two aspects of the display on the EDNA require discussion, as well. Individual responses indicate that reading data on the EDNA is a problem. Only two ratings were in the acceptable range in this category; four participants provided a rating of "Borderline," one provided a rating of "Moderately Unacceptable," and one provided a rating of "Extremely Unacceptable" when rating the ease of reading data on the EDNA. In addition, display size was revealed as a potential problem based upon individual responses. Five responses were in the acceptable range; however, two participants rated the EDNA as "Borderline," two participants rated the device as "Moderately Unacceptable" and one participant rated it as "Extremely Unacceptable" in the Display Size category. One can surmise that, in some cases, these categories are related; two participants indicated they were unhappy with the "small screen," and that it was "hard to read, even worse in the sun." Six individuals specified difficulty reading the screen in direct sunlight; e.g., "I needed to shade the screen to see anything"; "could not see display in direct sunlight"; "can't see screen well with sunglasses on, had to take them off to complete (the) task." One participant simply specified "screen brightness" as one of his least favorite features.

Other constructive comments were provided; two participants indicated that it is important that the device is radio frequency connected or capable.

4.1.2.2 With Chemical Gear

The means and standard deviations for user responses to the acceptability ratings for the EDNA laptop in the chemical gear condition are included in Figure 7. The means for both reading data and perceived portability are in the unacceptable range, indicating problems with both of these areas on the EDNA.

Laptop Computers – EDNA with Chemical Gear

	Completely Acceptable	Reasonably Acceptable	Borderline	Moderately Unacceptable	Extremely Unacceptable
Pointing Device		▲			
Entering Data		▲			
Reading Data			▲		
Perceived Portability			▲		
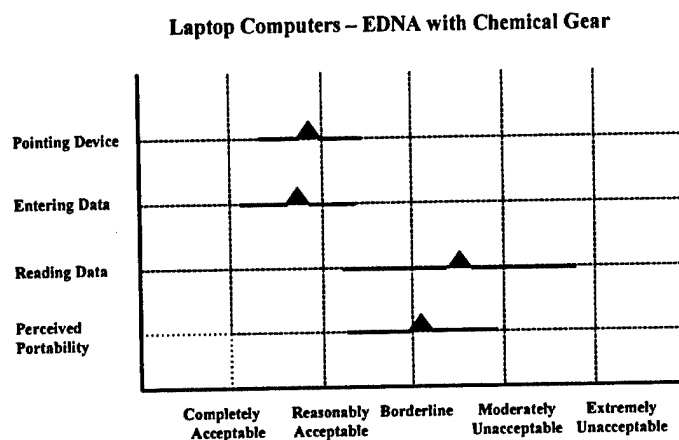
Figure 7. Means and Deviations – EDNA Laptop Computer with Chemical Gear

18
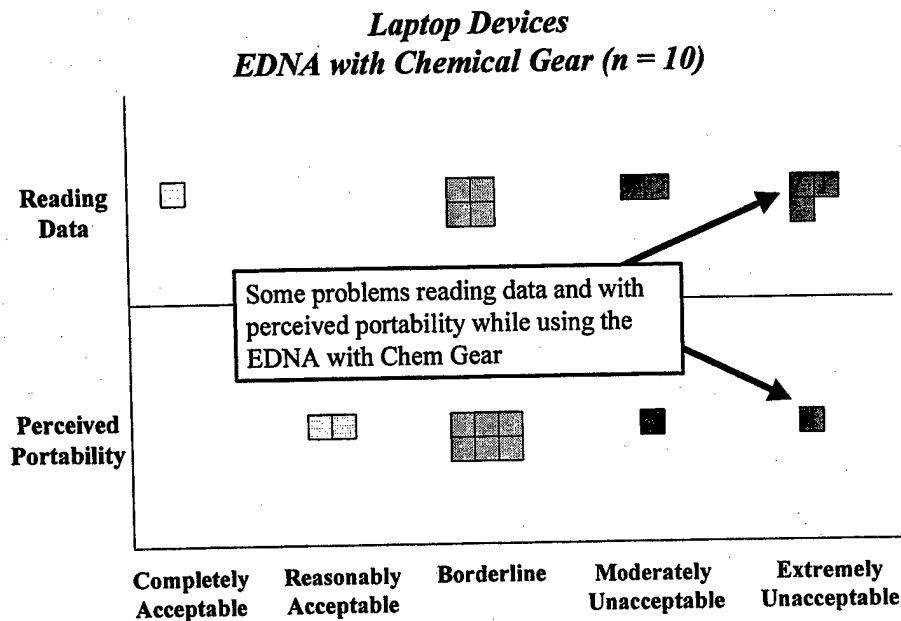
Figure 8. Individual Ratings for EDNA Laptop Computer with Chemical Gear

Participant responses during the chemical gear condition indicated problems with reading data and with perceived portability on the EDNA laptop (Figure 8). After using the device while wearing chemical gear, only one participant rated the ability to read data on EDNA in the acceptable range. Four participants rated the ability to read data on the EDNA as "Borderline," two participants rated the ability as "Moderately Unacceptable," and three participants rated the ability as "Extremely Unacceptable." The problem with reading data in chemical gear is slightly more pronounced than it was in the regular condition. Six participants classified the screen and its visibility as a least favorite feature of the device, e.g., "screen unreadable," "hard to see in sunlight," "screen (is) too dark in sunlight" or, simply, "screen." One additional participant specified problems with this aspect of the device with his more general comments; "very hard to see in direct sunlight and with chem. mask."

In the Perceived Portability category, only two participants rated the EDNA in the acceptable range; each of these participants provided ratings of "Reasonably Acceptable." Six participants rated the perceived portability of the device as "Borderline," one participant rated the device as "Moderately Unacceptable," and one participant rated the device as "Extremely Unacceptable." Four individuals provided comments indicating that the EDNA was "too heavy" and "bulky"; "it's like carrying a sack of potatoes."

Other constructive comments related to the EDNA in the chemical gear condition referenced the keypad of the device. More than three individuals found that the "buttons worked well with gloves," that the "raised keys made it easy to type," and that the "letters are spaced well," with the caveat that the buttons are "still too tough to press."

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4.1.3 ITRONIX GoBook.

The Itronix GoBook laptop computer has a standard QWERTY keyboard. The input device options are a keyboard touchpad with three-button control, or a touch screen that can be accessed via the stylus. It weighs approximately seven and one-half pounds.

4.1.3.1 Without Chemical Gear

The means and standard deviations of user responses to the Itronix GoBook in the non-chemical gear condition are presented in Figure 9. While no means are in the unacceptable range, the standard deviation in the Apparent Ruggedization category extends into the unacceptable range.

Laptop Computers – Itronic GoBook

Display Size
Computer Size
Apparent Ruggedization
Layout
Pointing Device
Navigating
Entering Data
Drop Down Menus
Reading Data
Perceived Portability

Completely Acceptable | Reasonably Acceptable | Borderline | Moderately Unacceptable | Extremely Unacceptable
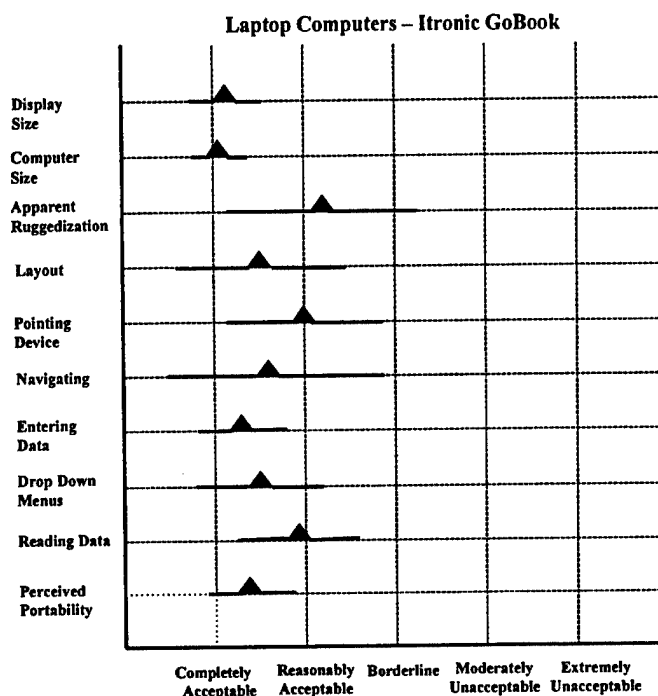
Figure 9. Means and Deviations – Itronix GoBook Laptop Computer

The compilation of individual user responses in the non-chemical gear condition indicates that the apparent ruggedization of the Itronix GoBook is a potential problem (Figure 10).

Laptop Devices
Itronix GoBook
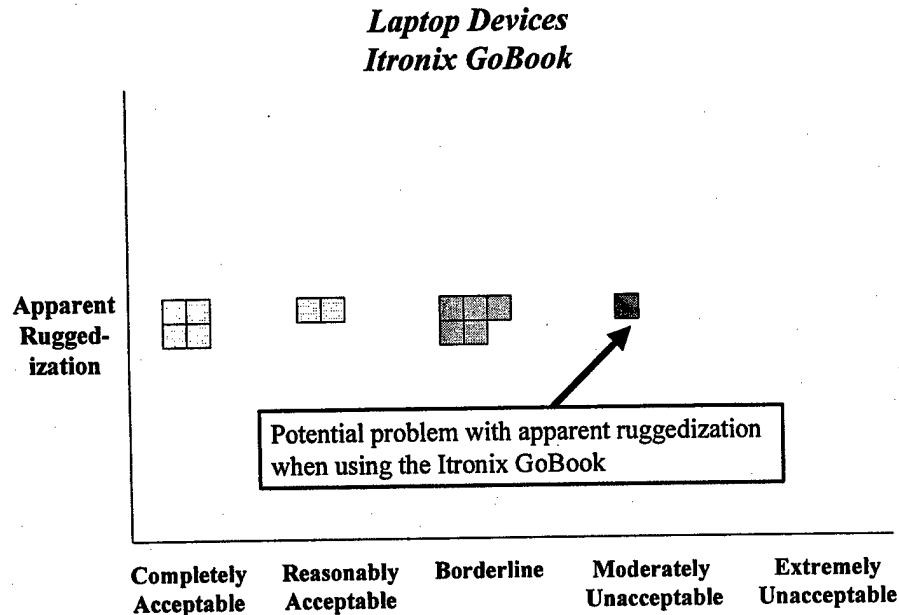
Figure 10. Individual Ratings for Itronix GoBook Laptop Computer

While six responses were in the acceptable range, five subjects rated the device as "Borderline" in regards to apparent ruggedization, while one participant rated the device "Moderately Unacceptable." Two participants remarked that the Itronix GoBook appeared very fragile while one participant commented that the machine was, simply, "not rugged." However, four participants listed the size and/or weight of the computer as their favorite feature: "It is almost everything to look for: size, layout, and accessibility."

More generally, two participants indicated concern regarding the behavior of the system when the screen was closed for transportation while the machine was still running. The machine went into sleep mode, and participants were no longer able to access the machine, as they did not possess the password. Also, two participants indicated some concern about the visibility and fading of the screen in direct sunlight. Four individuals suggested that the mouse was too sensitive or difficult to use (with two individuals classifying it as "very touchy"). Specific to the keyboard, one participant indicated that the right shift button was too far over, while another participant pointed out that "keyboard keys tend to hide behind other keys when typing."

4.1.3.2 With Chemical Gear

The means and standard deviations of user responses to the Itronix GoBook in the chemical gear condition are presented in Figure 11. While none of the means are in the unacceptable range, the standard deviation of the Entering Data category extends slightly into the unacceptable range, suggesting the slight potential for a problem entering data on the Itronix GoBook in the chemical gear condition.

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Laptop Computers - Itronix GoBook with Chemical Gear
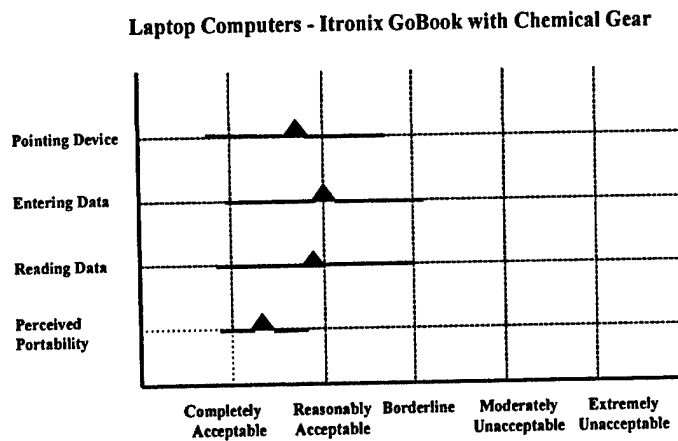
Figure 11. Means and Deviations – Itronix GoBook Laptop Computer with Chemical Gear

The compilation of individual user responses provides a very slight indication that entering data on the Itronix GoBook while wearing chemical gear is a potential problem. While eight participants rated the device in the acceptable range for the Entering Data category, three participants provided a rating of "Borderline," and one participant rated the Itronix GoBook "Moderately Unacceptable" (Figure 12).

Laptop Devices
Itronix GoBook with Chemical Gear

Potential problem entering
data with the Itronix GoBook
while wearing Chem Gear

| Completely Acceptable | Reasonably Acceptable | Borderline | Moderately Unacceptable | Extremely Unacceptable |
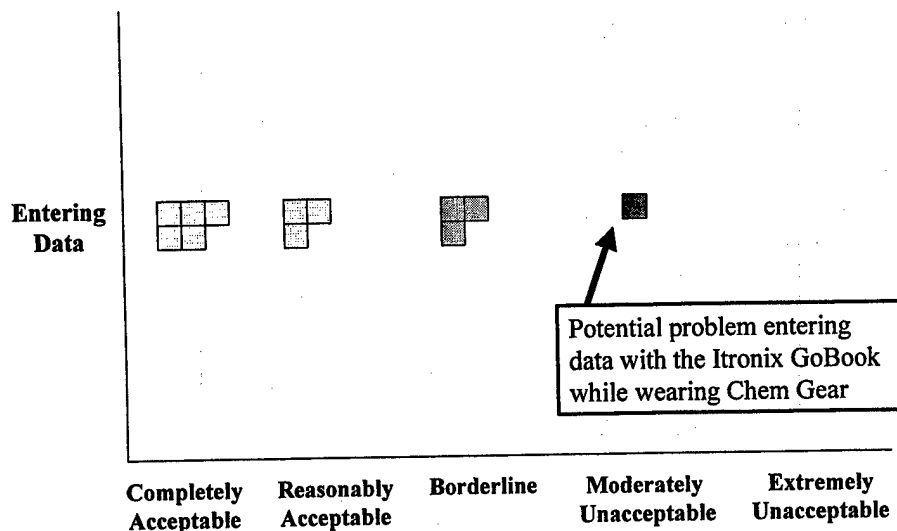
<u>Figure 12.</u> Individual Ratings for Itronix GoBook Laptop Computer with Chemical Gear

While two participants remarked on the ease of using the touch screen and keyboard when wearing gloves, and two other participants listed the button-style pointing device as their favorite feature on this device, six individuals indicated some level of difficulty with the mouse. For one subject, the "mouse pad (was) a little awkward"; for another, it was "hard to see the mouse icon when moving it around"; another subject simply stated that the pointing device was unacceptable, but did not indicate which pointing device he was referring to. Furthermore, two individuals pointed out that the keyboard keys were too small and too close together to effectively use while wearing chemical gear. It should be noted that, as with other laptop devices, the Itronix GoBook had multiple methods for entering data or navigating with the pointing device (e.g., touch screen, mouse button, touchpad); the individuals were not required to rank these features separate from one another.

More generally, two participants provided positive comments indicating that the equipment was light and compact. One participant listed it as "all-around the best" laptop he dealt with.

Conversely, two individuals had trouble with the screen and display on the Itronix GoBook, suggesting that it may have been a bit difficult to read.

4.1.4 Panasonic Toughbook 28

The Panasonic Toughbook 28 laptop computer has a standard QWERTY keyboard. The input device options are a keyboard touchpad with two-button control, or a touch screen that can be accessed via the stylus. It weighs approximately nine pounds.

4.1.4.1 Without Chemical Gear

The means and standard deviations of user responses to the Panasonic Toughbook in the non-chemical gear condition are presented in Figure 13. No means or standard deviations are in the unacceptable range for this device in this condition.
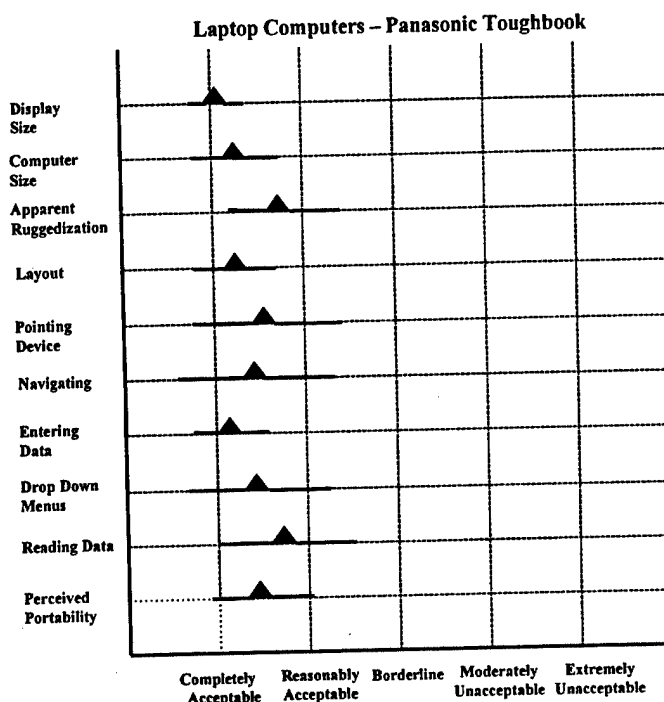
Figure 13. Means and Deviations – Panasonic Toughbook Laptop Computer

When users were not wearing chemical gear, no problems or potential problems for the Panasonic Toughbook laptop computer were revealed through individual user ratings. Participants provided various positive comments, including three participants who specified the touch screen as their favorite feature on this device. For example, after using the device in the regular condition, one participant was certain that "touch screen is a must with chem. gear!! Love it." Two participants classified the size and weight of the device as their favorite feature, while another two participants provided positive comments about the rugged design of the Panasonic Toughbook.

Other comments indicate that the screen may have been difficult to see in direct sunlight for two individuals. Furthermore, there were two indications of difficulty using the mouse and touchpad. Two other participants remarked that, while the stylus is quite useful, it is also highly likely to get lost.

4.1.4.2 With Chemical Gear

The means and standard deviations of user responses to the Panasonic Toughbook in the chemical gear condition are presented in Figure 14. While none of the means are in the unacceptable range, the standard deviation of the Pointing Device category extends slightly into the unacceptable range, suggesting the slight potential for a problem with the pointing device on the Panasonic Toughbook in the chemical gear condition.

Laptop Computers - Panasonic Toughbook with Chemical Gear

Pointing Device

Entering Data

Reading Data

Perceived
Portability

Completely   Reasonably   Borderline   Moderately   Extremely
Acceptable   Acceptable   Unacceptable Unacceptable
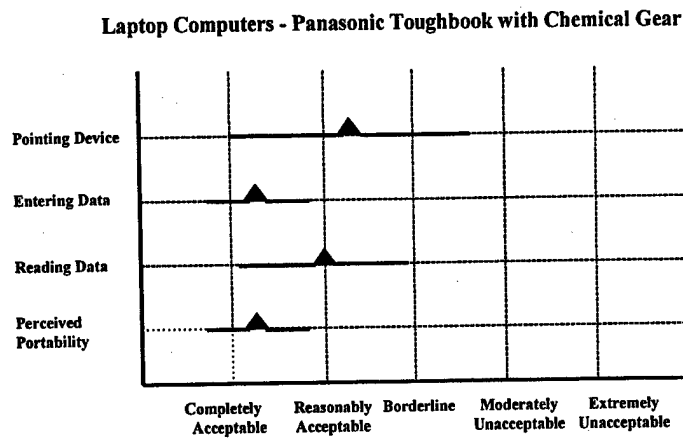
Figure 14. Means and Deviations – Panasonic Toughbook Laptop Computer with Chemical Gear

Laptop Devices
Panasonic Toughbook with Chemical Gear

Pointing
Device

Potential problem using pointing device with
Panasonic Toughbook while wearing Chem Gear

Completely   Reasonably   Borderline   Moderately   Extremely
Acceptable   Acceptable   Unacceptable Unacceptable
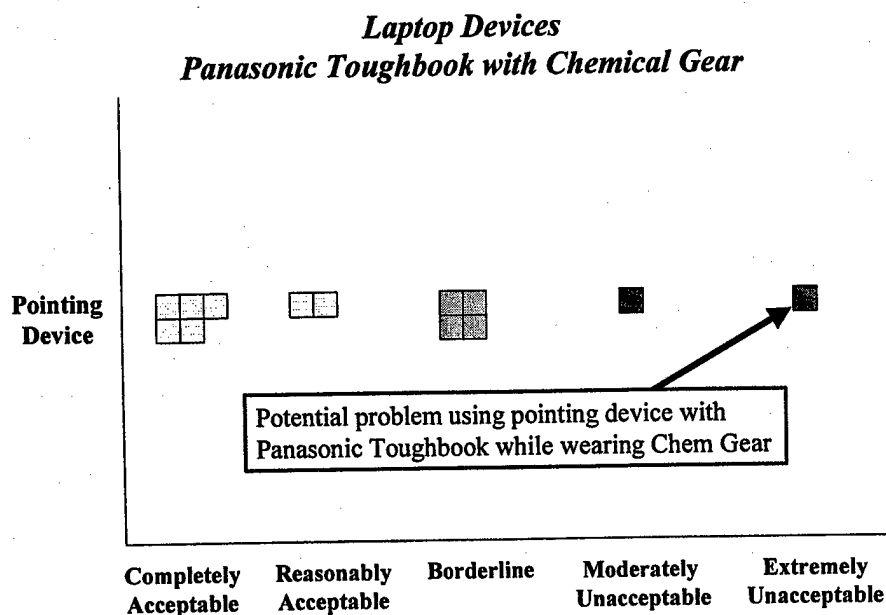
Figure 15. Individual Ratings for Panasonic Toughbook Laptop Computer with Chemical Gear

Subject responses during the chemical gear condition indicated a potential problem using the pointing device with the Panasonic Toughbook (Figure 15). While seven participants did

rate the device in the acceptable range, four participants rated the pointing device as "Borderline," one participant rated it "Moderately Unacceptable," and one participant rated it "Extremely Unacceptable" after accessing the Panasonic Toughbook while wearing chemical gear. Likewise, the comments provided regarding the use of the pointing device were both positive and negative. Five participants were very positive about the stylus, which they used with the touch screen as opposed to manipulating the mouse pad while in chemical gear; however, one individual added the caveat that the stylus would quickly get lost. Another individual pointed out that the "pointer was great because you don't have to try and manipulate the mouse pad with bulky gloves on." Still, six participants pointed out that the mouse was difficult to use with chemical gear, and one participant added that the stylus was difficult to use as well; e.g., the "touchpad (was) very hard to use with heat and chem. gear," the "mouse and stylus (were) very poor, difficult to maneuver," the "mouse pad (was) not as sensitive to gloves," or "the mouse pad was hard to move with gloves," and "touchpad classified as borderline, stylus as completely acceptable."

In general, participants had positive remarks about the display, touch screen, and keyboard. The touch screen, stylus and large keypad keys all were listed twice as favorite features on the device.

Three participants indicated that they had difficulty using the keyboard while wearing gloves, with one individual suggesting that a raised keyboard might be easier to access in this condition.

4.1.5 Paravant Scorpion

The Paravant Scorpion laptop computer has a standard QWERTY keyboard. The input device is a fingertip-joystick with a two-button control. This device does not have a touch screen. It weighs approximately eleven pounds.

4.1.5.1 Without Chemical Gear

The means and standard deviations of user responses to the Paravant Scorpion in the non-chemical gear condition are presented in Figure 16. While none of the means are in the unacceptable range, the standard deviations of both the Pointing Device and Navigation categories extend into the unacceptable range, suggesting the slight potential for problems with the pointing device and navigation on the Paravant Scorpion in the non-chemical gear condition.

Laptop Computers – Paravant Scorpion

	Completely Acceptable	Reasonably Acceptable	Borderline	Moderately Unacceptable	Extremely Unacceptable
Display Size					
Computer Size					
Apparent Ruggedization					
Layout					
Pointing Device					
Navigating					
Entering Data					
Drop Down Menus					
Reading Data					
Perceived Portability					
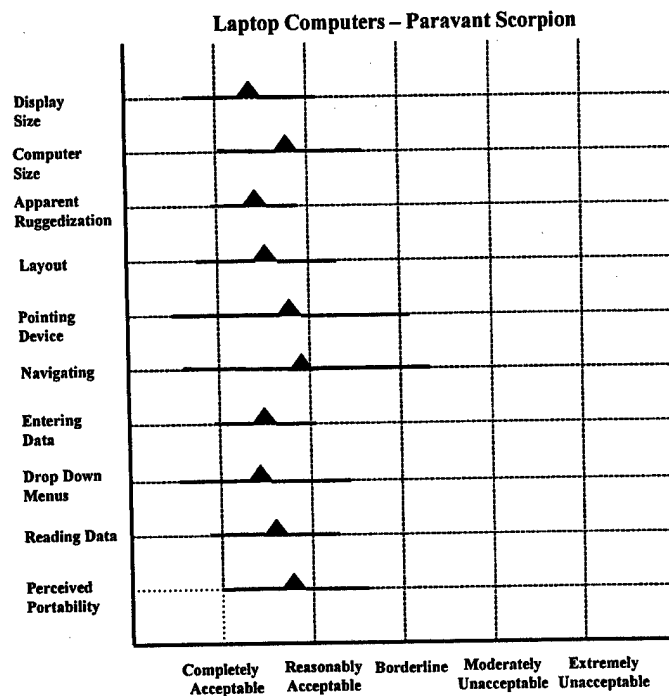
Figure 16. Means and Deviations – Paravant Scorpion Laptop Computer

Laptop Devices
Paravant Scorpion

Potential problems with pointing device and navigation when using the Paravant Scorpion

Pointing Device

Navigation

Completely Acceptable	Reasonably Acceptable	Borderline	Moderately Unacceptable	Extremely Unacceptable
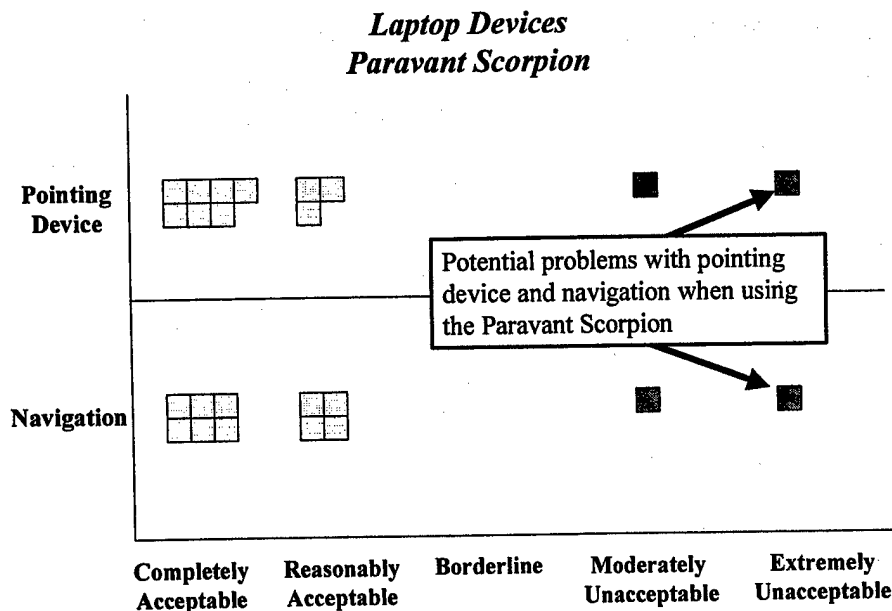
Figure 17. Individual Ratings for Paravant Scorpion Laptop Computer

Individual user responses to the Paravant Scorpion when not wearing chemical gear indicated two potential problem areas: navigation, and accessing the machine using the pointing device (Figure 17). In each area, this suggestion of a potential problem is slight. Ten

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participants rated accessing the Paravant Scorpion with the pointing device as in the acceptable range, while two participants rated this access "Moderately Unacceptable" or "Extremely Unacceptable." One individual specified the "mouse adaptor" as his least favorite feature of the device. However, few additional comments were available to triangulate this result.

Ten participants also rated navigation on the Paravant Scorpion in the acceptable range, while two participants rated this aspect of the device as "Moderately Unacceptable" or "Extremely Unacceptable." Only one comment specific to navigation was recorded, indicating that the Paravant Scorpion was "easy to navigate." One individual who provided a rating outside of the acceptable range expressed frustration overall, as the interface in which he was working was not functioning correctly. This software interface malfunction – not specific to the device itself – made it somewhat difficult for this user to successfully navigate through the program.

Two participants commented positively on the fact that the keyboard appeared water resistant. Two additional participants provided positive comments about the mouse and easy navigation capability. Other favorable comments were recorded regarding good screen visibility in direct sunlight.

Participants overwhelmingly indicated that the device was too heavy and/or bulky, with seven of twelve participants specifying this complaint in their responses.

4.1.5.2 With Chemical Gear

The means and standard deviations of user responses to the Paravant Scorpion in the chemical gear condition are presented in Figure 18. No means or standard deviations are in the unacceptable range for this device in this condition.

Laptop Computers - Paravant Scorpion with Chemical Gear
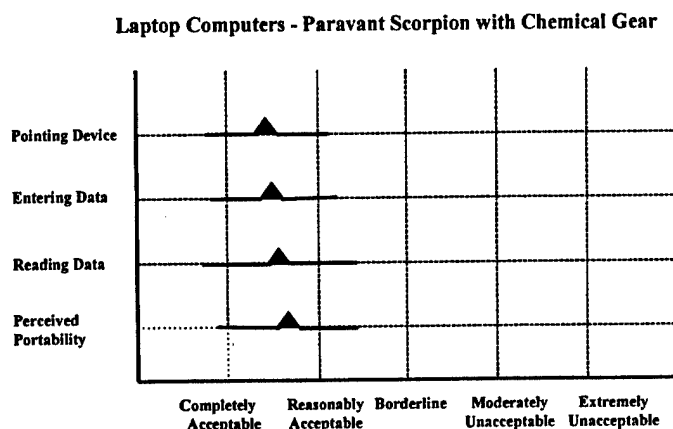
Figure 18. Means and Deviations – Paravant Scorpion Laptop Computer with Chemical Gear

In the chemical gear condition, the Paravant Scorpion did not show any problems or potential problems. Participants responded particularly favorably to the keyboard layout and its ease of use; five participants classified the keyboard and keys as well spaced, of good size and height, and easy to maneuver when wearing chemical gear. It should be noted that one participant did remark that he had difficulty with the keyboard, stating that he "had to hold (his) hands away so (he) wouldn't bump other keys."

4.1.6 Rankings for Laptop Devices

Statistical analysis of the rankings may show if one laptop device is preferred over the others. Using the χ^2 analysis, the analysis is done on the "Most Preferred" rankings provided by participants. If the distribution is equal, the expected value for each configuration is 2.4 (n = 12). With four (4) degrees of freedom (df = k-1) and α = .05, the critical value is 9.488.

In the non-chemical gear condition, the calculation yields $\chi^2 = 5.501$. Since $\chi^2 < 9.488$, the null hypothesis cannot be rejected and therefore the data did not provide significant evidence that the subjects had a statistical preference for a particular laptop device in the non-chemical gear condition. In the chemical gear condition, the calculation yields $\chi^2 = 3.833$. Since, again, $\chi^2 < 9.488$, the null hypothesis cannot be rejected and therefore the data did not provide significant evidence that the subjects had a statistical preference for a particular laptop device in the chemical gear condition. Even though this factor is not statistically significant in either condition, the distribution is not as strong due to the study's small sample size; thus, other analysis methods were used to evaluate device preferences.

Overall, visual inspection of ranking data for the laptop devices substantiates findings from the rating data; while no device was clearly defined as the most preferred, users least preferred the EDNA device when not wearing chemical gear (see Figure 19) and while wearing chemical gear (see Figure 20).

Laptop Preference
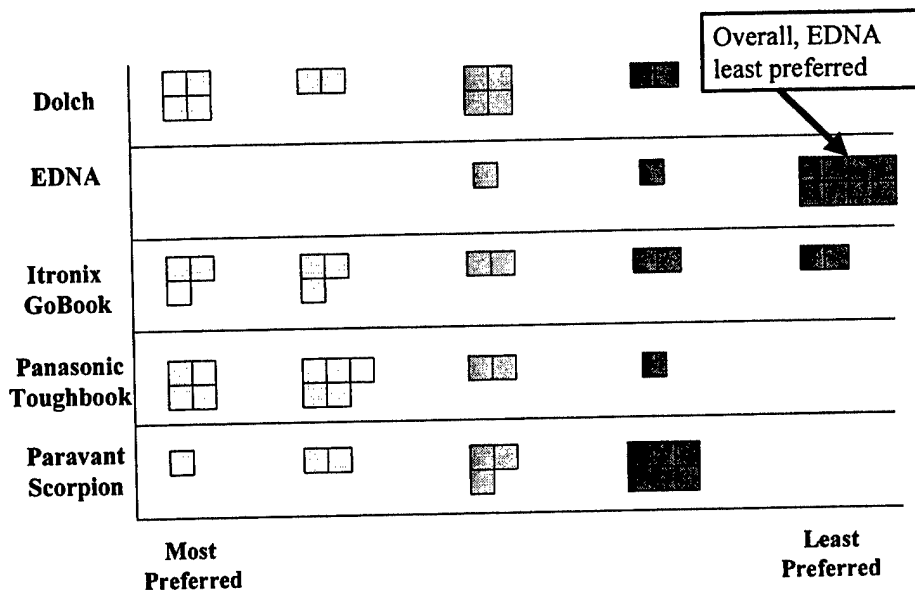
Figure 19. Rankings for Laptop Devices
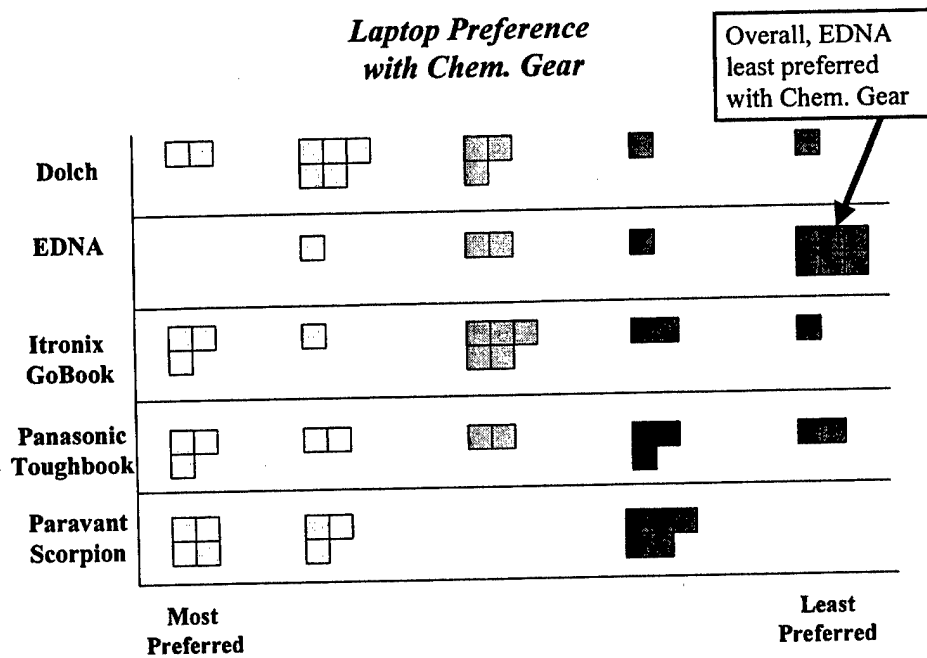
Figure 20. Rankings for Laptop Devices With Chemical Gear

4.2 Handheld computers

4.2.1 Dolphin 7400

The Dolphin 7400 handheld computer has an onscreen standard QWERTY keyboard, and an alphanumeric hard keypad. The input device options are the keypad, or a touch screen that can be accessed via the stylus. The device weighs approximately one and one-half pounds.

4.2.1.1 Without Chemical Gear

The means and standard deviations of user responses to the Dolphin 7400 in the non-chemical gear condition are presented in Figure 21. While none of the means are in the unacceptable range, note that the standard deviations of the Layout and Entering Data categories extend into the unacceptable range, suggesting a varying potential for problems with these features on the Dolphin 7400 in the non-chemical gear condition.

Handheld Computers – Dolphin 7400

Display Size
Computer Size
Apparent Ruggedization
Layout
Pointing Device
Navigating
Entering Data
Drop Down Menus
Reading Data
Perceived Portability

Completely Acceptable   Reasonably Acceptable   Borderline   Moderately Unacceptable   Extremely Unacceptable
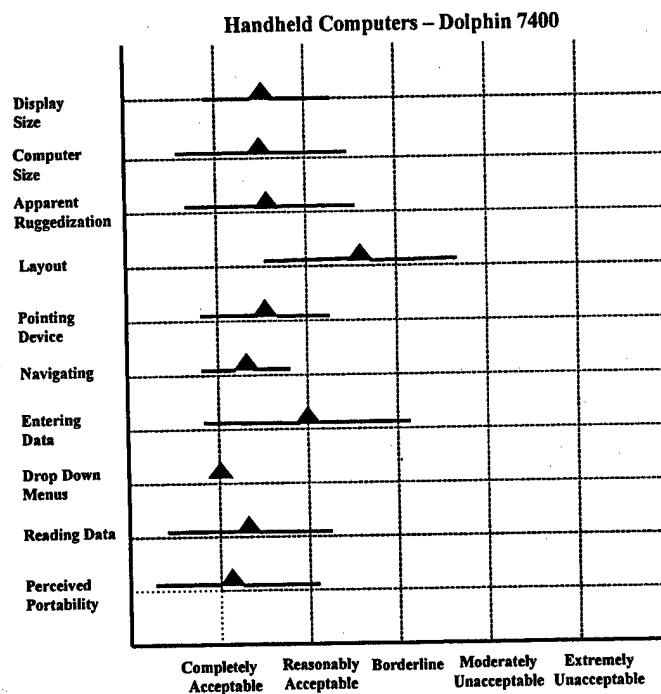
<u>Figure 21.</u> Means and Deviations – Dolphin 7400 Handheld Computer

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Handheld Devices
Dolphin

Figure 22. Individual Ratings for Dolphin 7400 Handheld Computer

Participant's scaled responses in the non-chemical gear condition indicate potential problems with both the Keyboard Layout and Entering Data categories on the Dolphin 7400. The trend of user responses supports that the keyboard layout has the stronger potential for problems. After accessing the device, only five total participants rated the keyboard layout on the Dolphin 7400 in the acceptable range. Five participants rated the keyboard layout of the device "Borderline," while one participant rated it "Moderately Unacceptable," and one participant rated it "Extremely Unacceptable" (Figure 22).

The strong indication of the scaled responses is further validated by the comments provided by the participants. Eight participants provided negative comments about the hard keyboard on the Dolphin 7400. "It's too hard to type with the keyboard…(for example, for) the backspace function you shouldn't have to repress the red button and backspace every time." "Selection on the manual keyboard was difficult." "Don't like the function keys for the manual keypad."

The indication of difficulty entering data on the Dolphin 7400 is less pronounced. Nine participants rated entering data on this device in the acceptable range. Only three ratings were in the unacceptable range; one participant rated the device as "Borderline" when entering data, and two participants rated it "Moderately Unacceptable." It should be noted that the strong indication that keyboard layout on the Dolphin 7400 posed a potential problem could have some impact on the perceived ease of entering data on the device.

Four participants also provided some negative response about the Dolphin 7400 on-screen keyboard, as well. While this keyboard option appeared preferable to the hard keyboard, it was "a bit awkward to get to." Other feedback indicated that using the on-screen keyboard

"was time consuming," and that there was concern that the "onscreen keyboard would block my view of the entry fields."

In general, positive comments from some participants indicate that the size of the device and the holding strap were popular features of the device. Two participants specified that they liked the size of the device. Also, two participants, when specifying their favorite feature of the device, listed the handheld strap of the Dolphin 7400.

The stylus was also listed as a favorable feature on the device, as three participants indicated a preference for the stylus and touch screen. However, three participants pointed out that the stylus "does not have a holding device," and "...should fit into unit so it is not easily lost."

4.2.1.2 With Chemical Gear

The means and standard deviations of user responses to the Dolphin 7400 in the chemical gear condition are presented in Figure 23. No means or standard deviations are in the unacceptable range for this device in this condition.

Handheld Computers – Dolphin 7400 with Chemical Gear
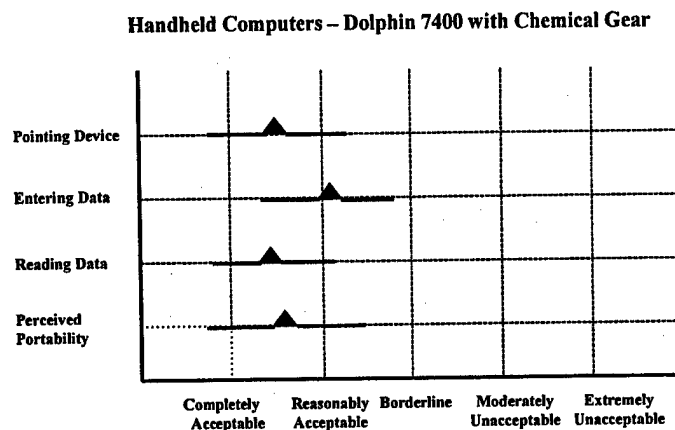
Figure 23. Means and Deviations – Dolphin 7400 Handheld Computer with Chemical Gear

User scaled responses indicate no problems or potential problems for the Dolphin 7400 in the chemical gear condition. However, open-ended responses suggest individual problems with the hard keypad on the Dolphin 7400 in the chemical gear condition (this is validated by the scaled responses to the Dolphin in the non-chemical gear condition). Six participants specifically commented that the hard keypad was difficult to use when wearing gloves. For example, "you wouldn't be able to type any info in on hard keypad while using gloves." Three of these participants felt that use of chemical gear made the hard keypad impossible to use; however, two others indicated that the hard keypad was still "acceptable" or "decent," even while the "manual keyboard could be slightly more user friendly." Two participants indicated

that, when wearing chemical gloves, the stylus was "awkward" or "hard to handle." In addition, two participants constructively pointed out that the device did not appear to have a stylus storage location. Given these comments, it is notable that the numeric rating responses did not indicate problems with the Dolphin 7400 in the chemical gear condition.

4.2.2 Intermec 700

The Intermec 700 handheld computer has an onscreen standard QWERTY keyboard, and 19-button hard keypad. The input device options are the keypad, or a touch screen that can be accessed via the stylus. The device weighs approximately one pound.

4.2.2.1 Without Chemical Gear

The means and standard deviations of user responses to the Intermec 700 in the non-chemical gear condition are presented in Figure 24. While none of the means are in the unacceptable range, note that the standard deviations for the Entering Data and Layout categories extend into the unacceptable range, suggesting the potential for problems entering data and with the layout of the Intermec 700 in the non-chemical gear condition.

Handheld Computers – Intermec 700
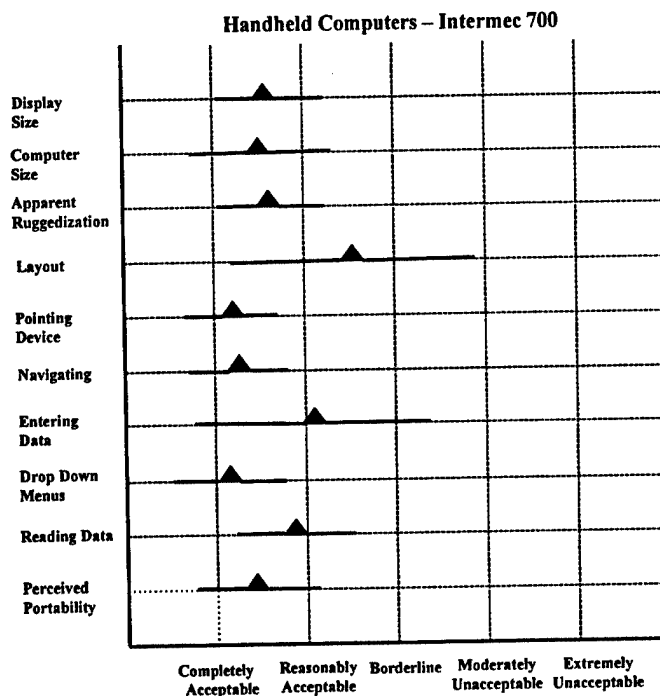
Figure 24. Means and Deviations – Intermec 700 Handheld Computer
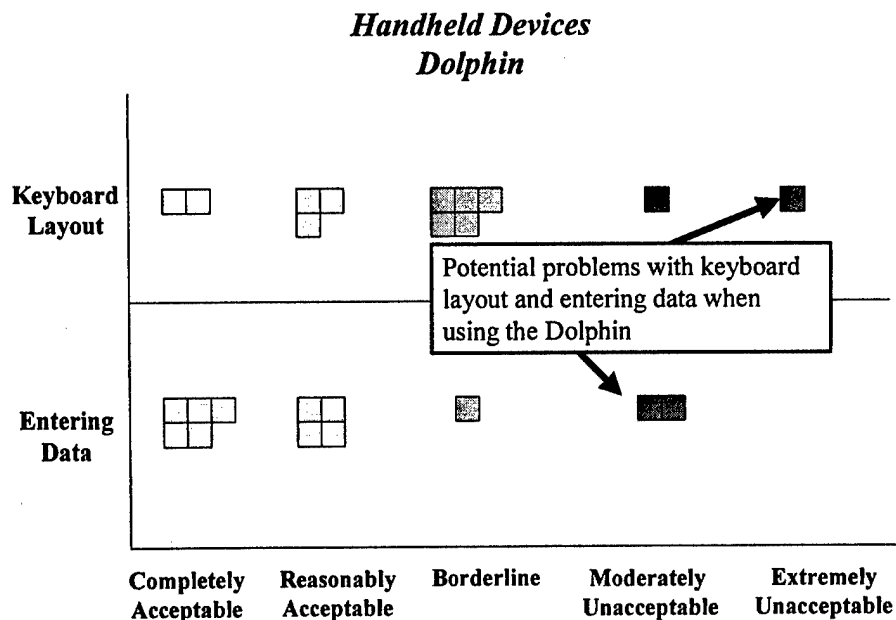
Handheld Devices
Intermec
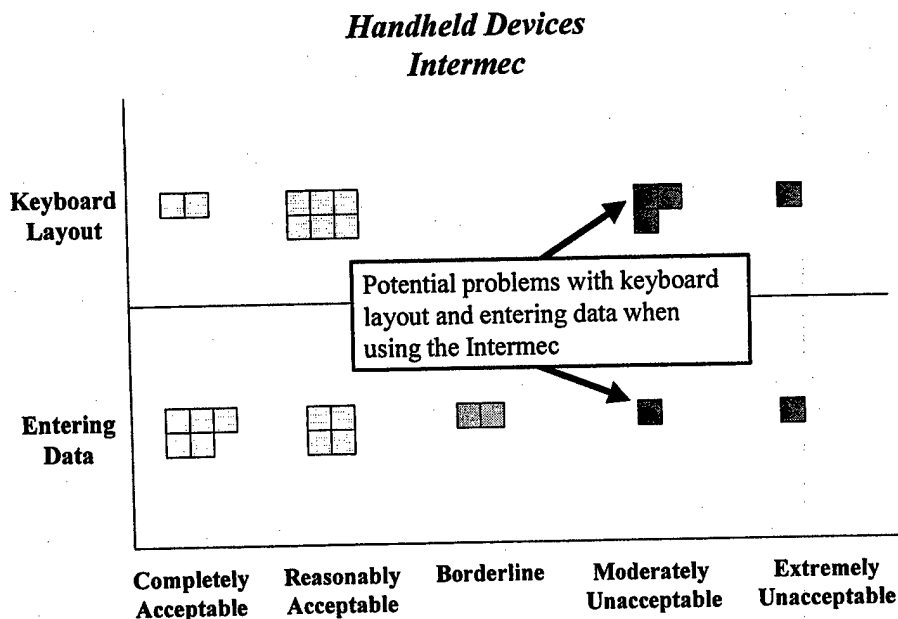
Figure 25. Individual Ratings for Intermec 700 Handheld Computer

Participant's scaled responses in the non-chemical gear condition indicate potential problems both with the keyboard layout and with entering data on the Intermec (Figure 25). While eight participants rated the keyboard layout on the Intermec in the acceptable range, three participants rated it as "Moderately Unacceptable," and one participant indicated that it was "Extremely Unacceptable." Nine participants specifically commented that they had difficulty with or simply did not like the hard keyboard on the Intermec, indicating that the hard keyboard was "confusing and a pain," "usable but confusing," or simply "not user friendly." Participants indicated that the "phone-style keyboard" was not an efficient way of entering alphabetic characters; "the manual keypad was very inadequate." One participant specified, "I didn't like that I had to switch CAPS lock for features other than capital letters."

The indication of potential problems with entering data on the Intermec is less extreme, but still present. Nine ratings of "Completely Acceptable" or "Reasonably Acceptable" were assigned for this aspect of the Intermec. However, four participants rated data entry on this device in the unacceptable range. There were two "Borderline" responses, one "Moderately Unacceptable" and one "Extremely Unacceptable" response. One individual supplied two ratings for the Entering Data category for the Intermec; he indicated that entering data using the stylus was "Reasonably Acceptable," while entering data using the hard keyboard was "Extremely Unacceptable." It appears the other responses may also be a reflection of the difficulty individuals experienced and expressed with the hard keyboard. Only one participant indicated that the "screen, numeric keypad is time consuming" – most likely suggesting that both the numeric and on-screen keyboard were time consuming. Four participants specified via comments that the onscreen keyboard was more acceptable, with three of these individuals listing the onscreen keyboard – and the ability to access it via the stylus – as their favorite feature.

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Other positive comments indicated the participants were pleased with the size of the device. More than two individuals remarked favorably about the overall size of the Intermec, including that the device had a "nice shape and size."

4.2.2.2 With Chemical Gear

The means and standard deviations of user responses to the Intermec 700 in the chemical gear condition are presented in Figure 26. While none of the means are in the unacceptable range, note that the standard deviation of the Entering Data category extends slightly into the unacceptable range, suggesting the slight potential for a problem entering data on the Intermec 700 when wearing chemical gear.

Handheld Computers - Intermec 700 with Chemical Gear
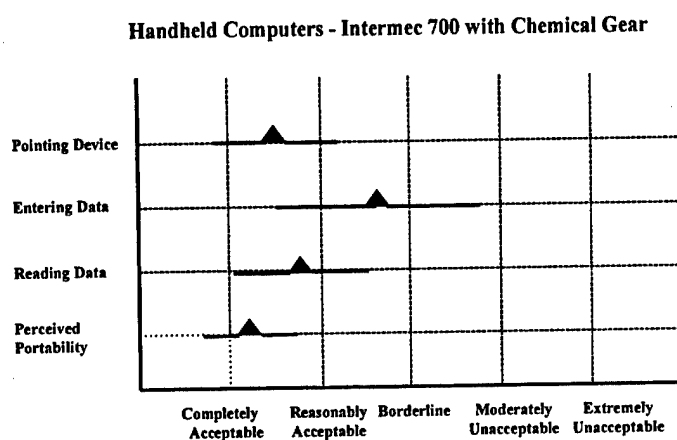
Figure 26. Means and Deviations – Intermec 700 Handheld Computer with Chemical Gear

Handheld Devices
Intermec with Chemical Gear
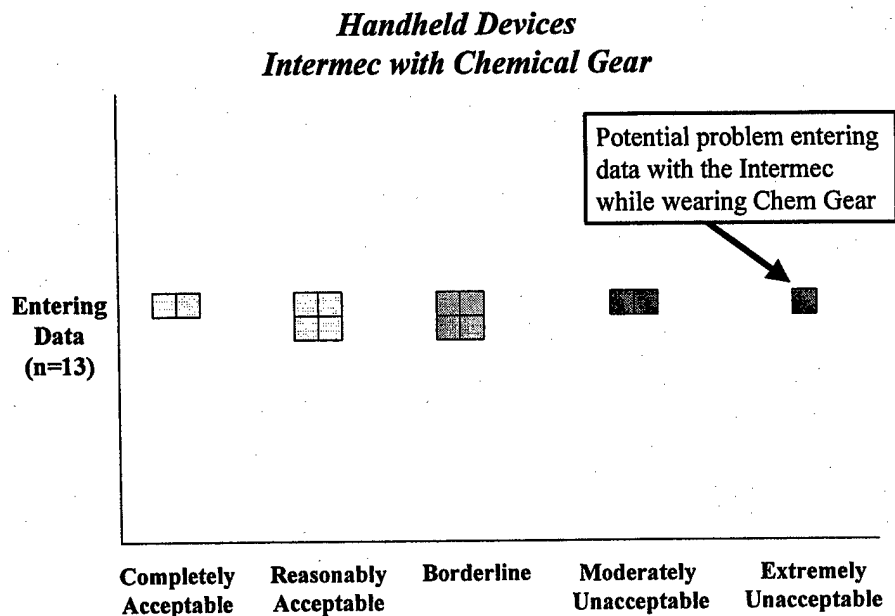
Figure 27. Individual Ratings for Intermec 700 Handheld Computer with Chemical Gear

Participant's scaled responses further indicate a potential problem entering data with the Intermec while wearing chemical gear. While six participants rated entering data on the Intermec in the acceptable range, six participants rated this aspect of the device in the unacceptable range, including two ratings of "Moderately Unacceptable" and one of "Extremely Unacceptable." Four participants rated entering data on the Intermec 700 as "Borderline" (Figure 27).

From the participant comments, it is probable that the difficulty entering data was primarily due to issues with the hard keyboard. Ten participants commented that the hard keyboard was difficult to use, e.g., "keypad was extremely unacceptable in entering data"; "forget using the hard keyboard (for) entering data"; "did not like the function/letter keys...(for) letter B, push twice"; "the keyboard (manual) is not user friendly. I don't like it!"

Where there are positive comments about entering data, either use of the stylus and/or use of the on-screen keyboard is implied. One participant remarked that "entering data (is) reasonably acceptable as long as you use pointer." Another participant pointed out that the "Screen keyboard (is) fast and easy to use."

Six participants provided positive remarks specific to the stylus. "The stylus is great, navigation is very easy. Good job!" "When in chemical gear you can use the pen to do everything." It should be noted that two participants indicated difficulty with the size of the stylus, as it was "hard to grip" and difficult to remove from the pen storage.

Other collaborated comments show that two users specified that they were quite pleased with the size of the Intermec, listing the size of the device as their favorite feature.

4.2.3 Rankings for Handheld Devices

Statistical analysis of the rankings may show if one handheld device is preferred over the others. Ranking data for the handheld computers was analyzed within the context of the usability issues most noted for these devices: keyboard layout, and entering data. Of particular interest in regards to these issues are the variances in preferences for the handheld devices when rating them for use entering alphabetic data, and when rating the devices for use entering numeric data. Using the χ^2 analysis, the analysis is done on the "Most Preferred" rankings provided by participants across these categories.

In the chemical gear condition, the following analysis was done to determine statistical significance of preference when entering alphabetic data on the handheld devices. If the distribution is equal, the expected value for each configuration is 5.5 (n = 11). Note that only eleven participants provided accurate rankings for both devices regarding entering alphabetic data in the chemical gear condition. With one (1) degree of freedom (df = k-1) and α = .05, the critical value is 3.8414.

In the chemical gear condition, the calculation yields χ^2 = .8181. Since χ^2 < 3.8414, the null hypothesis cannot be rejected and therefore the data did not provide significant evidence that the subjects had a statistical preference for a particular handheld device when entering alphabetic data in the chemical gear condition. In the non-chemical gear condition, the effect reflects these results found in the chemical gear condition. If the distribution is similar across responses to the device, the expected value for each configuration is 6 (n = 12). In the non-chemical gear condition, the calculation yields χ^2 = .3333. Since, again, χ^2 < 3.8414, the null hypothesis cannot be rejected and therefore the data did not provide significant evidence that the subjects had a statistical preference for a particular handheld device when entering alphabetic data in the non-chemical gear condition.

When entering numeric data on the handheld device in the chemical gear condition, the expected value for each configuration is 6 (n = 12). The calculation yields χ^2 = 0. Since χ^2 < 3.8414, the null hypothesis cannot be rejected and therefore the data did not provide significant evidence that the subjects had a statistical preference for a particular handheld device when entering numeric data in the chemical gear condition. Likewise, when entering numeric data on the handheld device in the non-chemical gear condition, the expected value for each configuration is 6.5 (n = 13). The calculation yields χ^2 = .692. Since, again, χ^2 < 3.8414 the null hypothesis cannot be rejected and therefore the data did not provide significant evidence that the subjects had a statistical preference for a particular handheld device when entering numeric data in the non-chemical gear condition.

Even though this factor is not statistically significant in any of the above conditions, it should be noted that the distribution is not as strong due to the study's small sample size; thus, other analysis methods were used in evaluating device preferences.

To further evaluate any possible device preferences, ranking data for the handheld computers was visually inspected within the context of the usability issues most noted for these devices: keyboard layout and entering data. Both the Dolphin and Intermec devices indicated potential usability problems in these areas. Close inspection of the ranking data indicates that users slightly preferred the Dolphin for alphabetical entry of data (Figure 28), while they slightly preferred the Intermec for numeric entry (Figure 29). While statistical differences were not

found, it is interesting to note that the Intermec used a telephone keypad arrangement (numerical with alpha characters available only with multiple key presses) and the Dolphin had an alphabetically arranged keyboard. These differences may account for the change in preference rankings. Note that no real preferences were found.

Alphabetic Data Entry
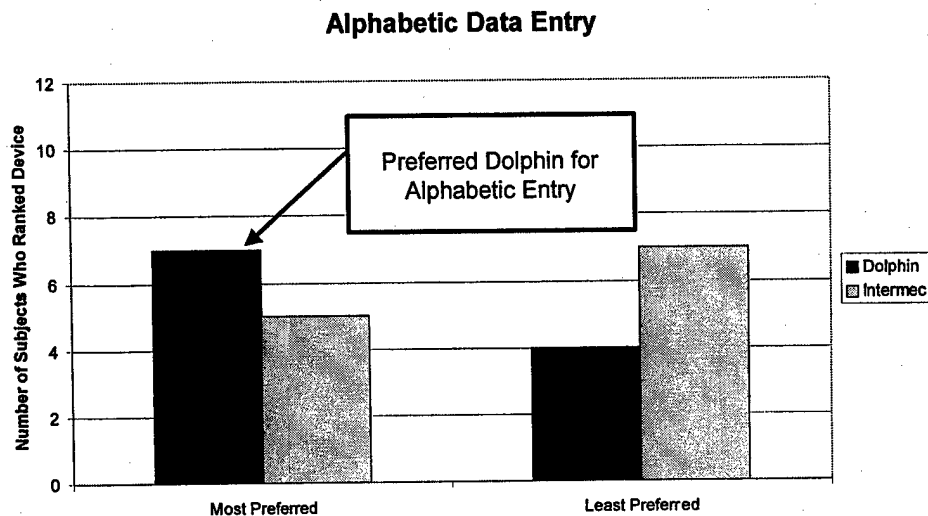
Figure 28. Rankings for Alphabetic Data Entry with Handheld Devices
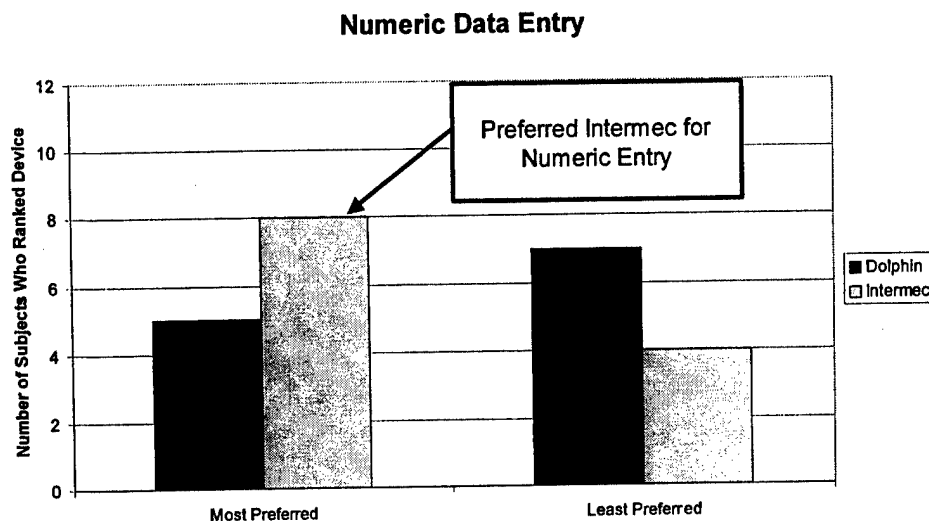
Numeric Data Entry

Figure 29. Rankings for Numeric Data Entry with Handheld Devices

4.3 Palm devices

4.3.1 Palm 515

The Palm 515 palm computer has an onscreen standard QWERTY keyboard, and handwriting recognition. The input device option is a touch screen that can be accessed via the stylus. The device weighs approximately five ounces.

4.3.1.1 Without Chemical Gear

The means and standard deviations of user responses to the Palm 515 in the non-chemical gear condition are presented in Figure 30. None of the means are in the unacceptable range. However, the standard deviations in the Apparent Ruggedization, Pointing Device, Entering Data, and Drop Down Menu categories extend (to varying degrees) into the unacceptable range, suggesting potential for problems with these categories on the Palm 515 in the non-chemical gear condition.

Palm Computers – Palm 515
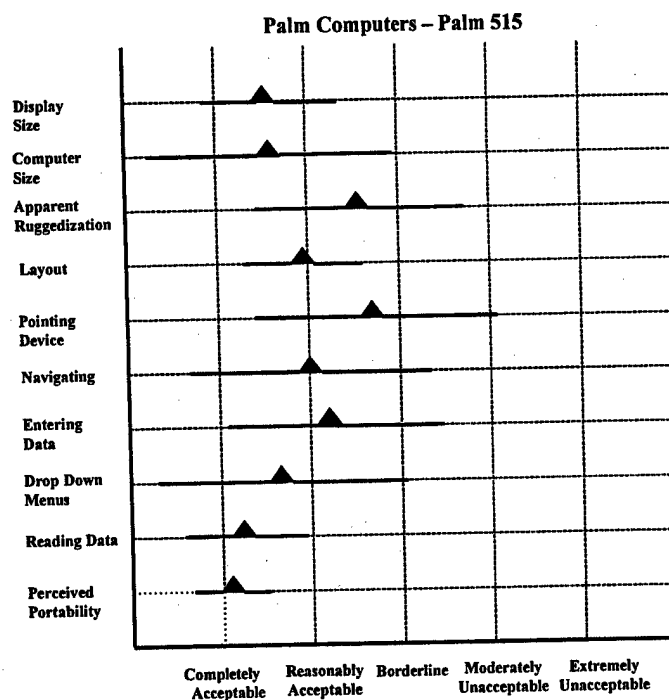
Figure 30. Means and Deviations – Palm 515 Palm Computer

Palm Devices
Palm 515
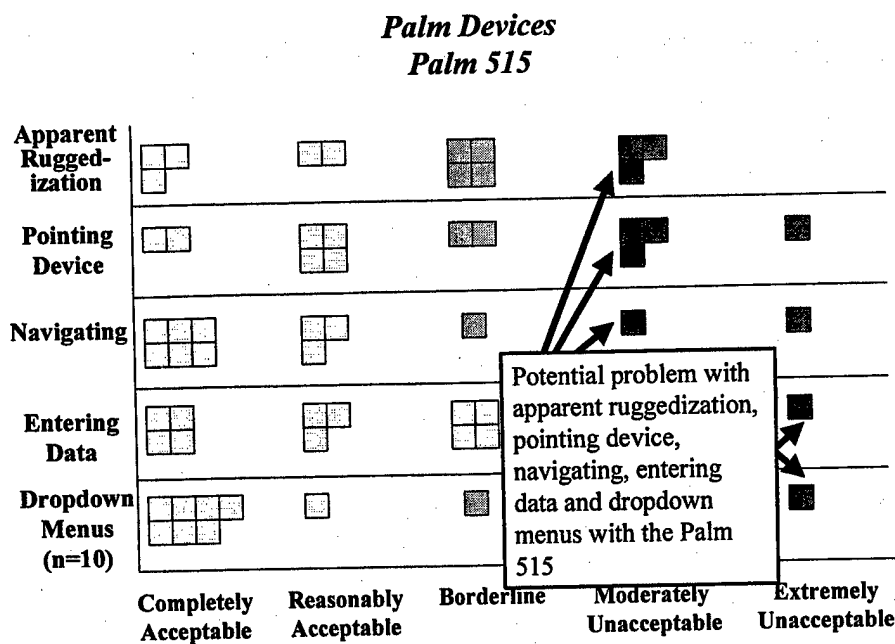
Figure 31. Individual Ratings for Palm 515 Palm Computer

Individual user responses to the Palm 515 when not wearing chemical gear indicated five potential problem areas: apparent ruggedization of the device, ease of using the pointing device,

navigation, ease of entering data, and use of drop down menus (Figure 31). The responses to each of these indicate varying degrees to which they may be problems.

As only five participants rated the apparent ruggedization of the Palm 515 in the acceptable range, the response does indicate reason for concern. Four individuals rated the apparent ruggedization of the device as "Borderline," and three rated it "Moderately Unacceptable." When asked about the apparent ruggedization of the device, four participants remarked that the Palm 515 was too small or fragile. It "does not feel like it could take much flightline abuse." "It isn't tough enough for crew chiefs." The "screen will need a scratch protector."

It should be noted that, overall, the size of the device still received the most positive response; five participants listed size as their favorite feature of the Palm 515. It "could be transported aircraft to aircraft without being cumbersome," and had excellent extra features (e.g., date book, notepad). While one participant was impressed that the "device (was) very small and easy to transport," another subject did indicate that the small size could increase the likelihood that the device may be lost or stolen.

The trend of the user responses regarding the pointing device on the Palm 515 clearly indicates a potential problem in this area. While six participants rated the device in the acceptable range, two participants rated the Palm 515 pointing device as "Borderline," three rated it "Moderately Unacceptable," and one rated it "Extremely Unacceptable." The individual comments support the provided ratings. Six participants reported some difficulty with the small pointing device. While it was unclear whether the difficulty was due to the stylus or to the user interface responsiveness, "certain options were very difficult to enter data into." Thus, various users classified this as difficulty with the pointing device, while others classified this as a data entry issue. Other user comments in this area include:

- Small pointing device, some entries didn't want to work.
- Sometimes system did not like to respond to pen/stylus.
- Had a hard time using pointing device.
- Screen did not respond well, had to search for points to hit.
- Some things were small and hard to read – pointer was difficult to get to register.

The user responses also show a slight indication that navigation on the Palm 515 may be a potential problem. Nine participants did rate the device in the acceptable range in this area; however, the remaining three respondents indicated that the device was "Borderline," "Moderately Unacceptable," and "Extremely Unacceptable" (one response in each category). Very few comments directly triangulate this result. One user commented that, while the on-screen keyboard was not a problem, he did not appreciate the navigation feature that required switching to different screens to enter numeric or alphabetic text. However, as navigation is a reflection of use of the pointing device, entering data, and access to drop down menus, the fact that potential problems are indicated in each of these areas strengthens the Navigation category rating response results.

Related to navigation, the remaining categories wherein potential problems are indicated support the above concept. Seven participants indicated that entering data on the Palm 515 was in the acceptable range; however, four individuals rated this aspect of the device as "Borderline," and one participant rated entering data on the Palm 515 as "Extremely Unacceptable."

Likewise, eight participants rated the drop down menus on the Palm 515 in the acceptable range, but one participant rated them as "Borderline," and one participant rated the drop down menus on the device as "Extremely Unacceptable." It should be noted that two individuals did not provide ratings for the drop down menus on the Palm 515 in this condition; but both commented that they had difficulty with the drop down menus – e.g., "hard time with getting drop downs to work," and "some drop down options did not work." Thus, while some users appreciated the availability of drop down options and the ease with which text was subsequently replaced, there was some difficulty with the drop down options on this device. However, what subjects had a particularly difficult time with was selecting and changing the characters in the time blocks of the application. "The drop down menu is hard to access. Could not put in times with stylus." Also, one user indicated a "difficulty in putting (the) date. Date block needs to be in bold. Drop down option is great, don't have to type it in." This action required the selection of the text to be changed; arrows to adjust various numbers could only be used once the text was properly selected. Three of the four comments that indicate difficulty with drop down menus specify these date-time blocks. Very little difficulty was observed with pure drop down functionality on the Palm 515 handheld.

4.3.1.2 With Chemical Gear

The means and standard deviations of user responses to the Palm 515 in the chemical gear condition are presented in Figure 32. None of the means are in the unacceptable range. However, note that the standard deviation of the Pointing Device category extends slightly into the unacceptable range, suggesting the slight potential for a problem with the pointing device on the Palm 515 in the chemical gear condition.
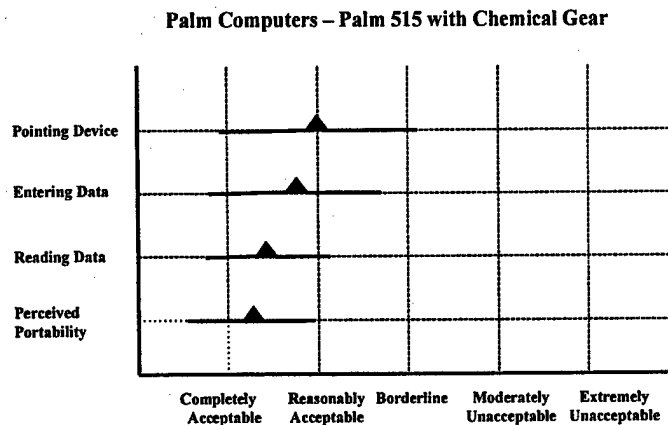
Figure 32. Means and Deviations of Palm 515 Palm Computer with Chemical Gear

Palm Devices
Palm 515 with Chemical Gear

Pointing Device				
Completely Acceptable	Reasonably Acceptable	Borderline	Moderately Unacceptable	Extremely Unacceptable

Potential problem using pointing device with the Palm 515 while wearing Chem Gear
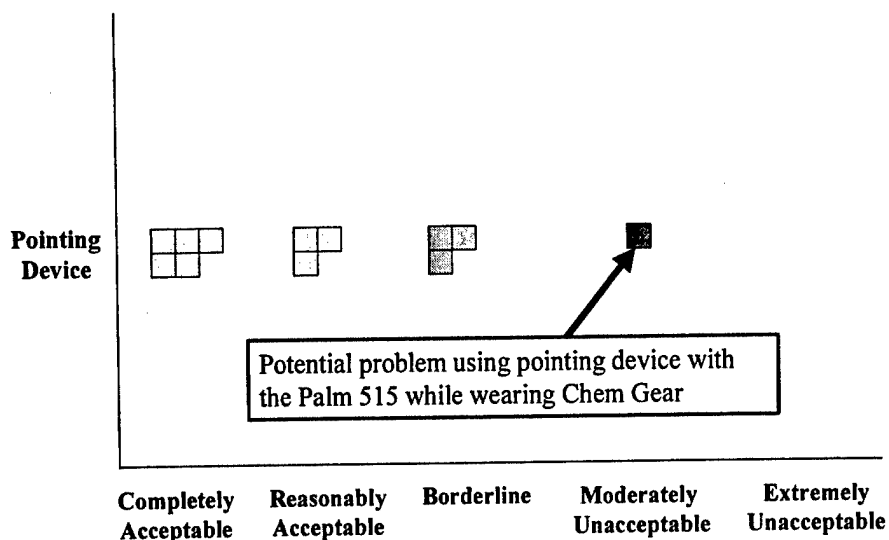
Figure 33. Individual Ratings for Palm 515 Palm Computer with Chemical Gear

User responses to the Palm 515 in the chemical gear condition indicate that using the pointing device while wearing chemical gear posed a potential problem. While eight individuals rated the device in the acceptable range, three participants rated the device "Borderline" and one participant rated the device "Moderately Unacceptable" when considering access to the Palm 515 using the pointing device (Figure 33). Six participants listed the stylus as their least favorite feature of the Palm 515 in the chemical gear condition. Overall, eight participants commented in some negative way on the use of the stylus in the chemical gear condition; the stylus was awkward to retrieve and difficult to hold when wearing chemical gloves, and, at times, it was somewhat inefficient as a data entry tool (particularly in the sensitive date and time blocks). One user indicated some concern that the device itself was too small to work with while wearing chemical gear.

4.3.2 Symbol Palm

The Symbol palm computer has an onscreen standard QWERTY keyboard, and handwriting recognition. The input device option is a touch screen that can be accessed via the stylus. The device weighs between 10 and 13 ounces, depending on configuration.

4.3.2.1 Without Chemical Gear

The means and standard deviations of user responses to the Symbol palm computer in the non-chemical gear condition are presented in Figure 34. Note that all of the means and standard deviations are in the acceptable range.

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Palm Computers – Symbol

| | Completely Acceptable | Reasonably Acceptable | Borderline | Moderately Unacceptable | Extremely Unacceptable |
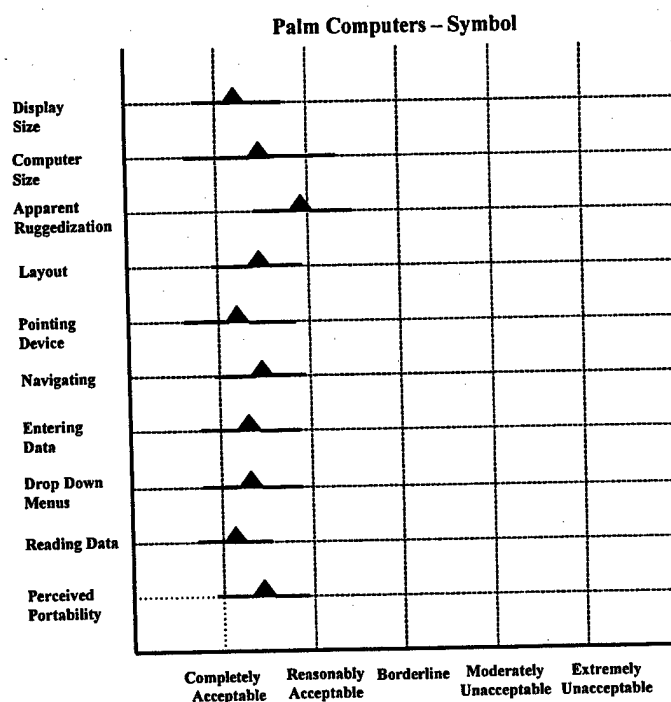
Figure 34. Means and Deviations – Symbol Palm Computer

When users were not wearing chemical gear, no problems or potential problems for the Symbol Palm device were revealed through user rankings.

Multiple positive comments indicate that the device was quite easy to use; one participant remarked that the Symbol Palm is a "very good device, very user friendly." Three participants simply listed the overall ease of use as their favorite feature of the device, while one simply pointed out, "I found nothing that I dislike." Two participants remarked positively on the portability of the device. Users expressed that they envisioned using this device primarily for tech data or checklists, as opposed to using it for opening and closing CAMS records.

Constructive comments regarding the Symbol Palm indicate that two participants may have had minor difficulty selecting items – one participant remarked that, when selecting one item, the item adjacent to it occasionally was selected instead, and another remarked that (as on) "the Palm 515, the letter and number keypad icons should be bigger" – and were somewhat uncertain about toggling the onscreen keypad to access both letters and numbers. This is true for both palm devices.

4.3.2.2 With Chemical Gear

The means and standard deviations of user responses to the Symbol palm computer in the chemical gear condition are presented in Figure 35. The means and standard deviations are all in the acceptable range for the Symbol Palm in the chemical gear condition.

Palm Computers – Symbol with Chemical Gear

Categories (top to bottom): Pointing Device, Entering Data, Reading Data, Perceived Portability

Scale (left to right): Completely Acceptable, Reasonably Acceptable, Borderline, Moderately Unacceptable, Extremely Unacceptable
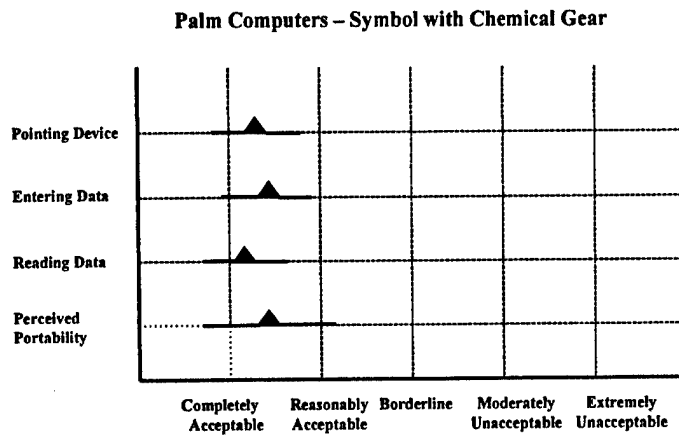
<u>Figure 35.</u> Means and Deviations – Symbol Palm Computer with Chemical Gear

No problems or potential problems for the Symbol Palm device were revealed through user rankings in the chemical gear condition. User responses were quite favorable, and included such subjective comments as: "AWESOME!" "EXCELLENT!!" and "Just as I expected, perfect." More specific comments indicated that participants appreciated the ease with which they could select a field, that the device appeared to be rugged, and that the screen was completely readable in direct sunlight.

4.3.3 Rankings for Palm Devices

Statistical analysis of the rankings may show if one palm device is preferred over the others. Using the χ^2 analysis, the analysis is done on the "Most Preferred" rankings provided by participants. If the distribution is equal, the expected value for each configuration is 6 (n = 12). With one (1) degree of freedom ($df = k-1$) and $\alpha = .05$, the critical value is 3.8414.

In the non-chemical gear condition, the calculation yields $\chi^2 = 1.333$. Since $\chi^2 < 3.8414$, the null hypothesis cannot be rejected and therefore the data did not provide significant evidence that the subjects had a statistical preference for a particular palm device in the non-chemical gear condition. In the chemical gear condition, the calculation yields $\chi^2 = .3333$. Since, again, $\chi^2 < 3.8414$, the null hypothesis cannot be rejected and therefore the data did not provide significant evidence that the subjects had a statistical preference for a particular palm device in the chemical gear condition. Even though this factor is not statistically significant in either condition, it should be noted that the distribution is not as strong due to the study's small sample size; thus, other analysis methods were used to evaluate device preferences.

Overall, visual inspection of ranking data for the palm devices substantiates findings from the rating data; users preferred the Symbol device while wearing chemical gear and when not wearing the extra gear (see Figure 36).

Overall Preference for Palms
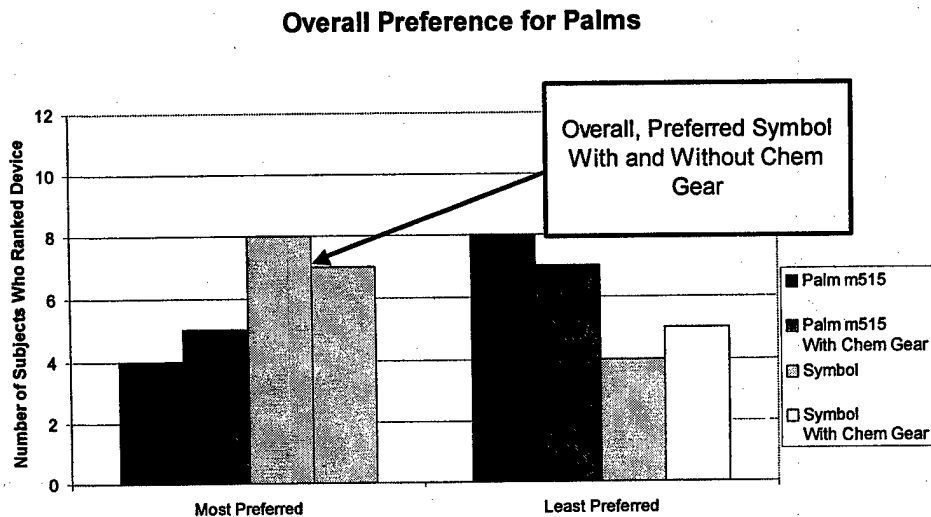
Figure 36. Overall Preference Rankings for Palm Computers

4.4 Alternative computers:

4.4.1 LXE

The LXE alternative computer has a 63-button quasi-QWERTY hard keypad. The input device options are the hard keyboard, or a touch screen that can be accessed via the stylus. The device weighs approximately one and one-half pounds.

4.4.1.1 Without Chemical Gear

The means and standard deviations of user responses to the LXE in the non-chemical gear condition are presented in Figure 37. Note that the mean response to the Reading Data category on the LXE in the non-chemical gear condition is in the unacceptable range, indicating a problem with this aspect of the device. Furthermore, the standard deviations in the Display Size, Keyboard Layout, Navigating, Entering Data, and Drop Down Menu categories extend into the unacceptable range, suggesting varying potential for a problems with these categories on the LXE.

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Alternative Computers – LXE
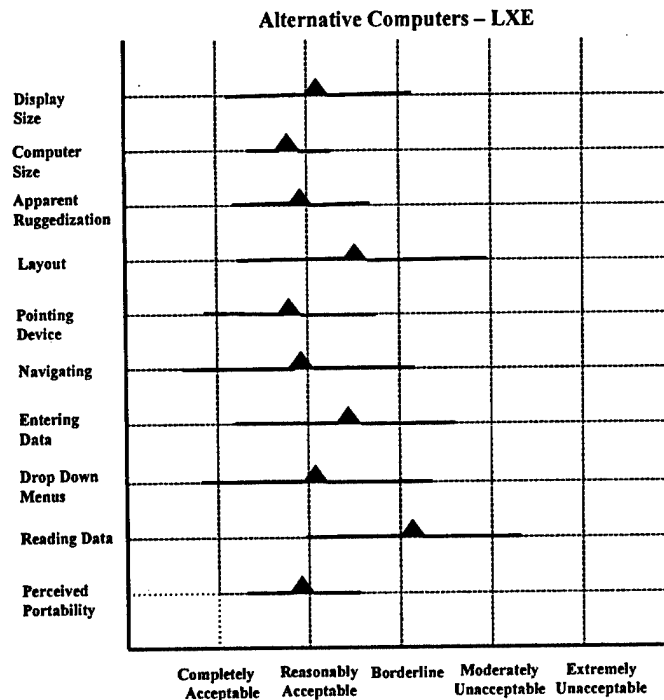
Figure 37. Means and Deviations – LXE Alternative Computer

Alternative Devices
LXE
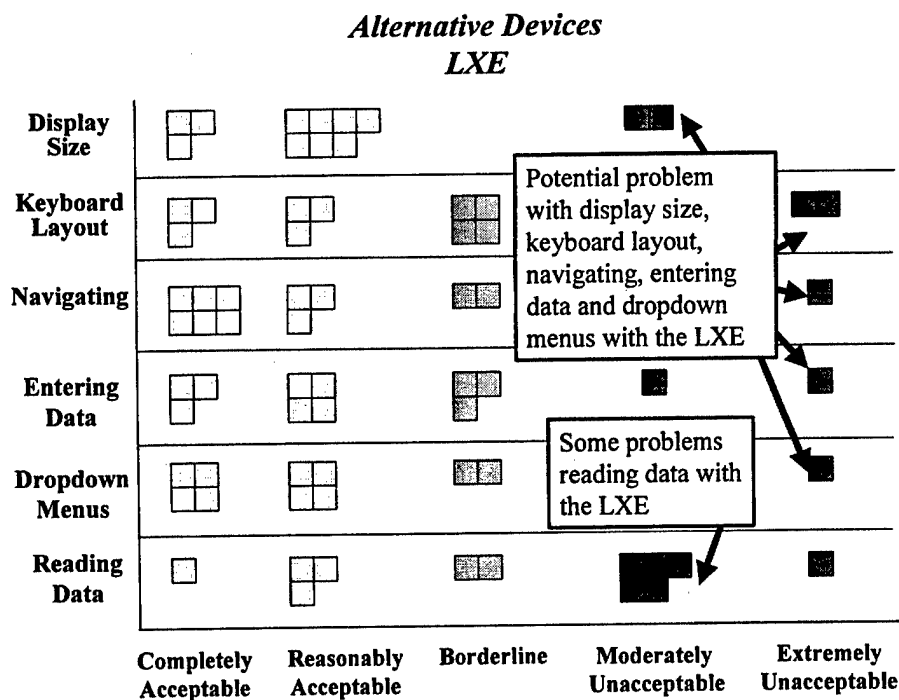
Figure 38. Individual Ratings for LXE Alternative Computer

Participant responses during the non-chemical gear condition identified problems with reading data on the LXE computer. Participant responses also identified potential for problems

with the display size, keyboard layout, navigating, entering data, and the drop down menus with the LXE computer (Figure 38).

Individual responses revealed the potential for problems with the display size on the LXE computer. While ten individuals rated the display size on this device in the acceptable range, two participants rated the display size on the LXE "Moderately Unacceptable." Only one participant commented specifically about the display size, simply remarking that his least favorite feature of the LXE computer was that the "screen was not very big." However, display issues are revealed more clearly by the ratings for the reading data category on the LXE. Participant responses revealed that reading data on the LXE computer is a problem. Only four participants rated this aspect of the device in the acceptable range. Two participants rated reading data on the LXE "Borderline," five participants rated it "Moderately Unacceptable," and one participant rated it "Extremely Unacceptable." Five participants specified their inability to read the display in sunlight as a least favorite feature of the device, and a total of seven participants remarked on their difficulty viewing the display in sunlight; e.g., "display (was) extremely hard to use in direct sunlight"; "readability of the display, screen very hard to see – too much glare"; "the screen wasn't the clearest I've seen"; "you can only hold the unit a certain way to read the screen"; "hard to see top tool bar in the sun."

Four areas related to navigating and entering data on the LXE computer were revealed as potential problems. Overall navigation on the LXE showed some potential for a problem; while nine individuals rated navigation on the LXE computer in the acceptable range (with six of those providing a rating of "Completely Acceptable"), two individuals rated it "Borderline," and one individual rated it "Extremely Unacceptable." It is not entirely clear if this navigation issue is related to the difficulty viewing the display in the sun; e.g., "hard to see top of screen."

Entering data on the LXE computer was also highlighted as a potential problem by user ratings; while seven individuals provided ratings of the device in the acceptable range, three participants rated entering data on the LXE as "Borderline," one rated it "Moderately Unacceptable," and one rated it "Extremely Unacceptable." Two participants did indicate that they appreciated the ability to enter data via multiple methods, specifically, the keypad and the stylus. All other comments relevant to entering data on the LXE were specific to the keyboard and its layout. Participant responses to the keyboard layout on the LXE computer highlight a potential problem with this area; although six individuals rated the LXE in the acceptable range for this category, four individuals rated the keyboard layout as "Borderline," and two participants rated it "Extremely Unacceptable." Five participants specified some aspect of the keyboard/keyboard layout as a least favorite feature of the device; overall, seven individuals commented on some difficulty with the keyboard and its layout. Although two individuals provided positive comments about the keypad – "the keypad (is) easy to read/use" – other individuals clarified their difficulties; a least favorite feature was that "it was not a traditional key configuration," or the "setup of keys," it had "no onscreen keys," it was "very hard to use," and the "keyboard layout takes time to get used to." One individual was positive about the ability to enter data "except for the space button – it needs to be bigger. I keep wanting to hit the enter button instead."

The final area relevant to navigation wherein potential problems were implied is the category of Use of Drop Down Menus on the device. Eight participants provided ratings in the acceptable range. However, two participants rated use of drop down menus on the LXE as "Borderline," and one participant rated this as "Extremely Unacceptable." While no comments

were provided that specifically corroborates these ratings, screen visibility may have impacted participant interactions with this feature.

In other general remarks, two participants specified that they were pleased with the "good size" of the LXE computer.

4.4.1.2 With Chemical Gear

The means and standard deviations of user responses to the LXE in the chemical gear condition are presented in Figure 39. Note that the mean response to the Reading Data category on the LXE in the chemical gear condition is in the unacceptable range, indicating a problem with this aspect of the device. Furthermore, the standard deviation in the Entering Data category extends into the unacceptable range, suggesting potential for a problem with this category on the LXE in the chemical gear condition.

Alternative Computers – LXE with Chemical Gear

	Completely Acceptable	Reasonably Acceptable	Borderline	Moderately Unacceptable	Extremely Unacceptable
Pointing Device	▲				
Entering Data		▲			
Reading Data			▲		
Perceived Portability	▲				
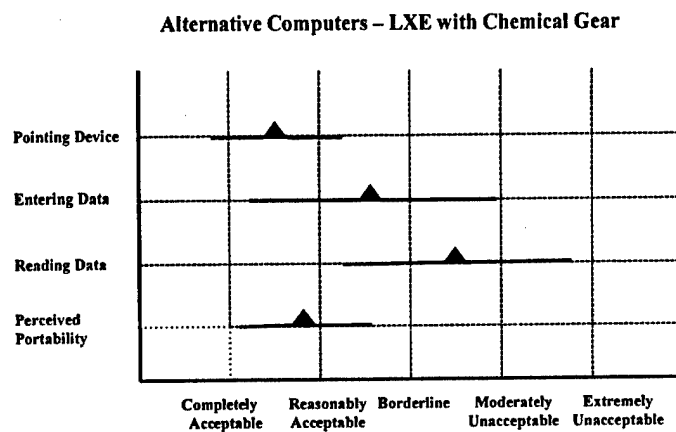
Figure 39. Means and Deviations - LXE Alternative Computer with Chemical Gear
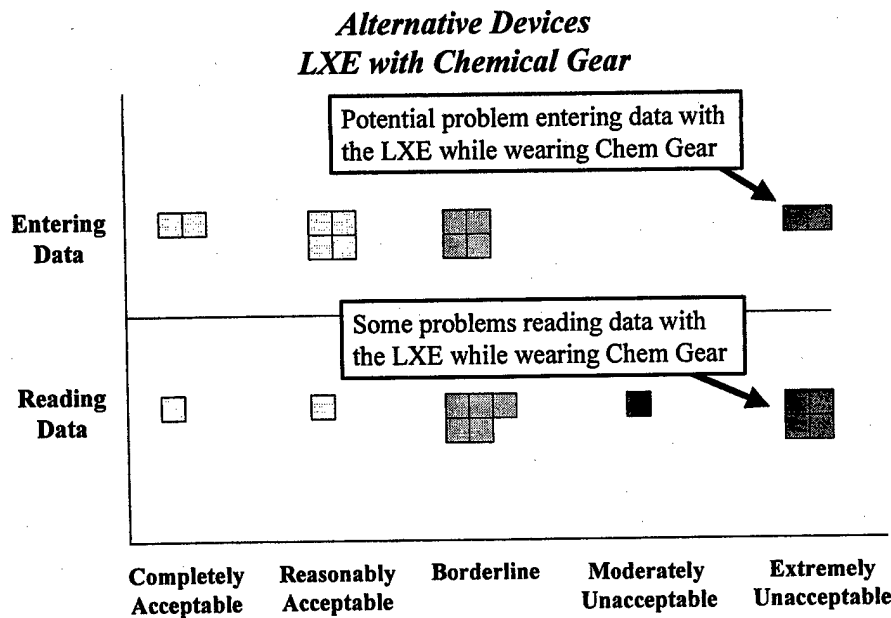
Figure 40. Individual Ratings for LXE Alternative Computer with Chemical Gear

Individual participant responses during the chemical gear condition further identified problems with reading data, and revealed the potential for problems with data entry, on the LXE computer (Figure 40). Six participants rated the device in the acceptable range for the Entering Data category in this condition. However, four individuals rated the device as "Borderline," and two individuals rated entering data on the LXE in the chemical gear condition as "Extremely Unacceptable." Specifically, six participants indicated that they had some difficulty using the keyboard due to the small size of the buttons, and three of these listed the keys/keypad as their least favorite feature on the device. "The keypad was hard to use with chemical gloves." "If you have bigger (thicker) gloves on, you will not be able to hit the case's hard keyboard." "It did seem that the keys were a little close together." "Buttons too small for gloves."

Participant responses further indicate that there is a problem reading data on the LXE in the chemical gear condition. Only two participants rated the device in the acceptable range for this category. Five participants rated the device as "Borderline," one participant rated the device as "Moderately Unacceptable," and four participants rated the reading data on the LXE as "Extremely Unacceptable." Seven participants commented that it was difficult to read the screen in sunlight due to glare, and four of these specified the display, or the glare on the display, as their least favorite features of the device. Some comments include: "the contrast between lights and darks needs more definition"; "the shadows from my gloves made it hard to see on the small screen. Had to move the unit around a lot to get a picture without the shadows"; and "extremely hard to see, even without chem. gear."

Three participants remarked positively regarding the small size of the LXE computer.

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4.4.2 Xplorer

The Xplorer alternative computer has an onscreen standard QWERTY keyboard. The input device option is a touch screen that can be accessed via the stylus.

4.4.2.1 Without Chemical Gear

The means and standard deviations of user responses to the Xplorer alternative computer in the non-chemical gear condition are presented in Figure 41. No means are in the unacceptable range. Only one category, Layout, was assigned ratings wherein the standard deviation extends into the unacceptable range, indicating the potential for a problem in this area.
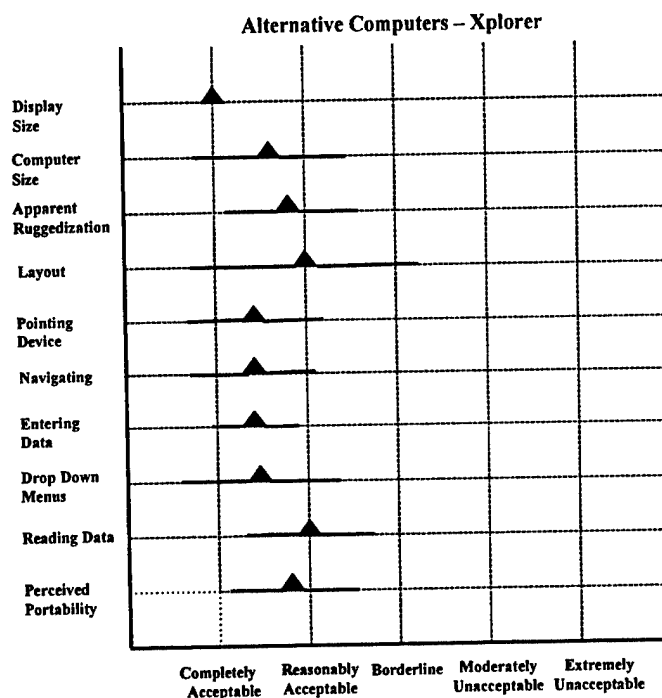
Figure 41. Means and Deviations – Xplorer Alternative Computer

Alternative Devices
Xplorer Slate

Keyboard
Layout

Potential problem with keyboard layout
when using the Xplorer

| Completely | Reasonably | Borderline | Moderately | Extremely |
| Acceptable · | Acceptable | | Unacceptable | Unacceptable |
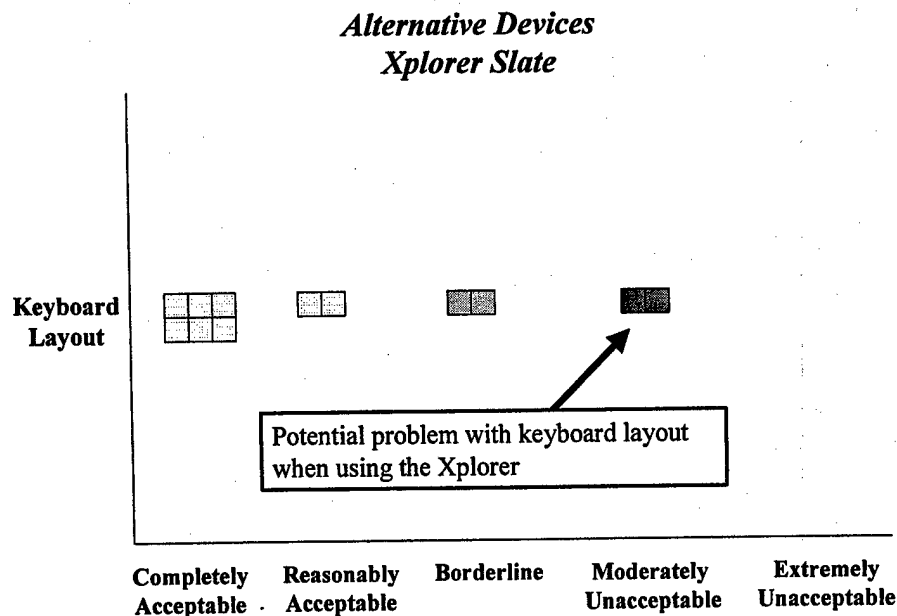
Figure 42. Individual Ratings for Xplorer Alternative Computer

Participant responses in the non-chemical gear condition identified some potential for problems with the keyboard layout on the Xplorer computer (Figure 42). After using the Xplorer computer without chemical gear, eight participants rated the keyboard layout on the device in the acceptable range. However, two participants rated the Xplorer keyboard layout as "Borderline," and two participants rated it as "Moderately Unacceptable." Only one individual specified the *lack* of a hard keyboard as his least favorite feature on the device. Other comments that illuminate any difficulty users may have had with the on-screen keyboard of the Xplorer include the following: "When carrying into sun, bumped by knee and ended up with extra characters on screen"; "keyboard/key sizes should be bigger... keys were small, I prefer using my fingers to type instead of stylus"; "had to keep moving keyboard out of the way." Four participants listed the touch screen and/or its "full, standard keys" as their favorite feature on the device.

There were very few general comments regarding the Xplorer computer during the non-chemical gear condition. Two individuals simply pointed out how much they liked the device: "outstanding device, overall probably my favorite"; "this device has to be the best one yet!"

Constructive comments regarding the Xplorer computer indicated that two participants had some difficulty with the weight of the computer, noting that the device was "definitely too heavy." Furthermore, two participants indicated concern that there was no apparent place to stow a pointing device/stylus for the device.

4.4.2.2 With Chemical Gear

The means and standard deviations of user responses to the Xplorer Slate in the chemical gear condition are presented in Figure 43. All of the means and standard deviations are in the acceptable range for the Xplorer Slate in the chemical gear condition.

Alternative Computers – Xplorer with Chemical Gear

| | Completely Acceptable | Reasonably Acceptable | Borderline | Moderately Unacceptable | Extremely Unacceptable |
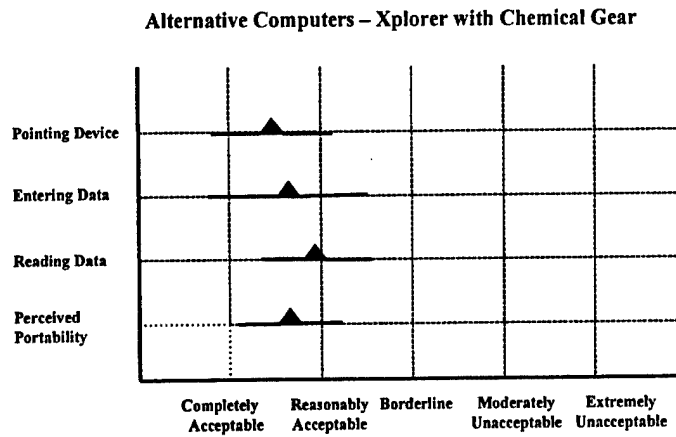
Figure 43. Means and Deviations – Xplorer Alternative Computer with Chemical Gear

There were very few comments regarding the Xplorer computer during the chemical gear condition. Constructive comments regarding the Xplorer computer indicated that participants had some difficulty with the weight of the computer – two participants noted that the device was too heavy. Two participants also commented that the readability of the screen was reduced due to a glare that was produced when using the Xplorer computer in direct sunlight.

5 Discussion

The purpose of this study was to provide a subjective judgment, based on standard usability testing methods, as to the usability of various mobile devices on the flightline. Based on participant comments, ratings and rankings, the devices can be categorized as follows:

1. *Usable as designed.* Comments, ratings and rankings revealed no problems or potential problems.
2. *Usable as currently designed, but with considerations for future designs.* Comments, ratings and rankings revealed potential problems, but no problems.
3. *Not usable as currently designed.* Comments, ratings and rankings revealed a problem or problems with the device on the flightline.

Using information collected in the study, each device has been assigned to an appropriate category.

5.1 Laptop Devices

5.1.1 Dolch

The Dolch computer met usability requirements for performing data collection type tasks on the flightline. The Dolch computer is *usable as currently designed, but with considerations for future designs.* While, overall, users provided positive comments, ratings and rankings for the device, it should be noted that when wearing chemical gear there were potential problems using the mouse touchpad. This was the least favorite feature of the device. Fingertip sensitivity when wearing chemical gloves is likely to be reduced; as such this may impact the user's ability to adequately interact with the mouse touchpad.

5.1.2 EDNA

Clearly the EDNA computer did not meet usability requirements for data collection on the flightline. The EDNA Computer is *not usable as currently designed.* Even the individual ranking data indicates that the EDNA was the device least preferred by users, both with and without chemical gear, when compared with the other laptops. Real usability problems were identified both with and without chem. gear for reading data and perceived portability. Users also indicated usability problems with the size of the device. Comments were explicit in terms of the inability to read the display screen, especially in the sunlight. In accordance with user comments, this device did not offer the portability requirements users want to have on the flightline. It is important to note that the EDNA was the only device that required a tethered power cable in order to operate. Along with the size and weight of the device, this umbilical led users to rate the computer as unacceptable for portability. In addition to these usability problems, many *potential* usability problems were also indicated on the EDNA. Six categories were identified as potential problems in the non-chemical gear condition: Display Size, Keyboard Layout, Pointing Device, Navigation, Entering Data, and Dropdown Menus.

5.1.3 Itronix GoBook

The Itronix GoBook computer met usability requirements for performing data collection type tasks on the flightline. The Itronix GoBook is *usable as currently designed, but with considerations for future designs.* Users only indicated one potential problem when using the device without chemical gear; this was in Perceived Ruggedization. It is important to note that

this is *perceived* ruggedization not *actual* ruggedization. Users believed that the device was not as rugged as it should be. This misconception might be overcome with training, familiarization or some modification to the design. When wearing chemical gear, participants indicated potential problems Entering Data. These potential problems related to using the pointing device or mouse with chemical gear. Fingertip sensitivity when wearing chemical gloves is likely to be reduced; this may impact the user's ability to adequately interact with the mouse.

5.1.4 Panasonic Toughbook

The Panasonic Toughbook computer met requirements for usability of the device for performing data collection type tasks on the flightline. The Panasonic Toughbook is *usable as currently designed, but with considerations for future designs*. While, overall, users provided positive comments, ratings and rankings for the device, it should be noted that when wearing chemical gear there was a potential usability problem when using the Pointing Device, specifically using the mouse. Fingertip sensitivity when wearing chemical gloves is likely to be reduced; this may impact the user's ability to adequately interact with the mouse.

5.1.5 Paravant Scorpion

The Paravant Scorpion computer met requirements for usability of the device for performing data collection type tasks on the flightline. The Paravant Scorpion is *usable as currently designed, but with considerations for future designs*. Users only indicated two potential problems when using the device without chemical gear: Pointing Device, and Navigation. Participants noted that the mouse adaptor was the reason for the unacceptable ratings in the Pointing Device category. No problems were indicated when using this device with chemical gear.

5.2 Handheld Devices

5.2.1 Dolphin 7400

The Dolphin 7400 handheld computer met usability requirements for data collection activities on the flightline. The Dolphin 7400 is *usable as currently designed, but with considerations for future designs*. Users indicated potential problems with the Keyboard Layout and Entering Data when not wearing chemical gear. This feedback is related to the arrangement of the keyboard, an alphabetical arrangement, as well as the use of function keys to input certain characters. The on-screen keyboard, while preferred to the hard keyboard, was also identified as potentially problematic by several users.

5.2.2 Intermec 700

The Intermec 700 handheld computer met usability requirements for data collection activities on the flightline. The Intermec 700 is *usable as currently designed, but with considerations for future designs*. Users indicated potential problems with Entering Data and the Keyboard Layout when not wearing chemical gear. This feedback is related to the arrangement of the keyboard, a telephone style arrangement. This arrangement required users to press keys multiple times at a certain rate to enter specific alphabetic characters. Users also indicated potential problems Entering Data when wearing chemical gear. Fingertip sensitivity while wearing chemical gear may have contributed to this concern.

5.3 Palm Devices

5.3.1 Palm 515

The Palm 515 is *usable as currently designed, but with considerations for future designs*. The Palm 515 computer met requirements for usability of the device for performing data collection type tasks on the flightline—no actual problems were identified when performing the analysis. However, there were five potential problems when not wearing the chemical gear and one when wearing gear. This number alone indicates that the device may not be as appropriate for flightline data collection as other devices available. The five potential usability problems were in these areas: Apparent Ruggedization, Pointing Device, Navigating, Entering Data, and Dropdown Menus. In chemical gear, users indicated potential problems with the Pointing Device. Most of the user comments related to issues associated with the small size of the device, the screen, and the seemingly fragile nature of this palm device.

5.3.2 Symbol

The Symbol computer met requirements for usability of the device for performing data collection type tasks on the flightline. The Symbol is *usable as designed.* This is the only device included in this evaluation that received ratings in the acceptable range for all categories, both with and without chemical gear. While participants used the stylus and onscreen keyboard as the primary method for inputting data on this device, they were aware that handwriting recognition is available as a feature on this device.

5.4 Alternative Devices

5.4.1 LXE

The LXE computer did not meet usability requirements for data collection on the flightline. The LXE is *not usable as currently designed.* Only one area was indicated as a real usability problem both with and without chemical gear; this was in Reading Data. This problem reading data was exacerbated when attempting to read the screen contents in the sunlight. In addition to this usability problem, five potential problems were also identified. These include Display Size, Keyboard Layout, Navigating, Entering Data and Dropdown Menus. These potential problems, which individually do not prohibit usability on the flightline, indicate some systemic problems with the usability of the device.

5.4.2 Xplorer

The Xplorer computer met requirements for usability of the device for performing data collection type tasks on the flightline. The Xplorer is *usable as currently designed, but with considerations for future designs*. Only one potential usability problem was identified with this computer: Keyboard Layout. This device only offered the on-screen keyboard. Users indicated this as a potential problem with the device.

6 Recommendations

Over the course of the study, individuals articulated several general concerns relevant to any consideration of e-tools for flightline maintenance activities. Behavior of the devices in the environments in which they will be used is important; devices should withstand heat, sand and sun exposure, and should also retain their level of accessibility in darkness. Particularly, screens and keypads should have lighting/backlighting capabilities in order to be easily navigated and used in various low lighting conditions.

Furthermore, familiarization with any e-tool requires a change in accepted general and individual processes. Users indicated that, while electronic access to information could be valuable to them, it is equally important that this access does not simply add an additional step to an activity. They expressed concern that, after entering data using an e-tool, they would still be required to interface with another device to update any information stores. Users expect that access to data using remote e-tools is immediate, and provides direct updates. Unless the system can be updated (and provide updates) real-time, the usability, and improvement to processes, is low.

During the course of the study, two device characteristics emerged as most desirable. Spontaneous remarks by the participants indicated that the touch screen was the most popular feature available across the devices. It allowed individuals to bypass difficult, confusing or simply undesired hard keyboards, and directly interface with the data being accessed. This was particularly true when individuals were restricted by chemical gear gloves, which reduced accuracy on a keyboard, and increased difficulty grasping a slender stylus. While the stylus is often provided as one means of accessing a touch screen, fingertip access is also a viable means of entering data via the touch screen. The other feature commonly mentioned as important was size of the device. As maintainers are accustomed to being encumbered by large manuals and toolboxes, a small portable device for maintenance data collection is extremely desirable.

Overall, the Symbol device stands out as the device most usable for data collection in flightline settings. Users indicated that this device might also be appropriate for display of checklist type technical data. This is consistent with information gathered during previous studies by AFRL (Donahoo, Gorman, Kancler, Quill, Revels & Goddard, 2002). The device offered a small footprint, a stylus and touch screen, handwriting recognition, and an on-screen keyboard.

The only two devices not recommended for use on the flightline for data collection were the EDNA and the LXE. Clearly, the EDNA had many complex usability problems that would prohibit use of the device for flightline data collection without major upgrades to all aspects of the computer. The LXE, on the other hand, may be suitable for flightline use if usability issues associated with the screen readability can be resolved. The recommendation for the LXE device is to reevaluate the screen being used so as to minimize problems reading the screen in sunlight. Consideration for other potential usability problems should also be given when making modifications to future designs.

Users indicated that the mouse is not acceptable as the primary means of entering data. Pointing devices on laptops, specifically the mouse type devices, caused users to note potential usability problems. This was especially apparent when wearing chemical gear. It is important to note that the pointing device problem was consistently identified as a potential problem with all

laptop devices (either with chemical gear or without). The recommendation is that use of pointing devices for flightline maintenance e-tools be minimized as a primary means of providing pointing capability to users. Users indicated the preference for the touch screen on these computing devices.

Given this information, it should be noted that certain input situations utilizing a touch screen might require peripheral pointing devices, such as a stylus. Some users expressed a preference for a stylus when using the touch screen with chemical gear, particularly for tasks requiring precision, such as utilizing handwriting recognition or the onscreen keyboard. Use of the handwriting recognition feature, or access to the onscreen keyboard when wearing chemical gear, may be more difficult if *only* fingertip access to the touch screen is available.

Users indicated keyboard layout on the handheld devices as potentially problematic. This was true for both devices. The Dolphin offered an alphabetically arranged keyboard and the Intermec offered a telephone style keyboard; both were identified as having potential usability problems without chemical gear on. This is consistent with other findings on keyboard arrangement; users – even hunt and peck typists – prefer the QWERTY style keyboard (arranged as it is on the standard keyboard) arrangement to other arrangements, such as alphabetical arrangements. It is important to note, however, that users indicated potential problems with the keyboard layout on the LXE device; this device mimicked a QWERTY arrangement, with the exception that the enter key, space bar, shift and backspace functions were relocated. User concerns with the keyboard had to do with the unusual placement of these keys. Finally, the Xplorer offered only the on-screen keyboard; users did not like this arrangement either. As a keyboard is somewhat essential to data entry – especially when entering large amounts of text – the recommendation is that *if* a hard keyboard is used, it should be a standard QWERTY arrangement. If an on-screen keyboard can be available, it should be included, but it should not be the only means of entering text.

As an alternative to having a hard keyboard or on-screen keyboard, users seemed to appreciate the handwriting recognition feature available on the Symbol and Palm 515 device. This capability allowed users to enter small amounts of text fairly quickly without the additional real estate required for a hard keyboard (alphabetical, QWERTY or telephone style). The recommendation is to include handwriting recognition capabilities on small devices as opposed to a hard keyboard. On-screen keyboards should still be available as an alternative to the handwriting recognition.

This usability test included evaluation of eleven mobile computing devices for collecting maintenance data in a flightline setting. Three usability categories for e-tools resulted from this test: 1) Usable as designed, 2) Usable as currently designed, but with considerations for future designs, and 3) not usable as currently designed. With regard to the first category, users identified the Symbol palm device as having no potential or actual usability problems for collection of data on the flightline. Clearly such a device is acceptable for maintenance data collection on the flightline. Of the eleven devices tested in this evaluation, ten devices were identified as having potential or real usability problems. Users identified eight devices as having potential usability problems either with or without chemical gear (i.e., classified in the second category). These devices are, in their current configuration, acceptable for flightline use; however, the potential problems identified for these devices should be addressed in future enhancements to these devices. Finally, users identified two devices in the third category: these devices were identified as having real usability problems. The EDNA computer had multiple

actual problems and multiple potential problems. These problems and potential problems seem to make this device unacceptable without major redesign of the system. The LXE device had one real problem along with several potential problems. Modifications to this device may make it suitable for flightline use, if care is given to the usability concerns identified.

7 References

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Appendix A. Device Specifications

Table III. Laptop Computer Specifications

Company	DOLCH	EDNA	Itronix	Panasonic	Paravant
Product	NotePAC Plus	Data not available	GoBook	Toughbook 28	Scorpion
Product Type	Laptop Computer	Laptop	Laptop Computer	Laptop Computer	Laptop Computer
Platform	MS Windows 98 or 2000		MS Windows 98 or 2000	MS Windows XP/2000	MS Windows 98/2000/NT/XP
Touch screen	No	No	Yes	Yes	No
Keyboard	Standard 87button QWERTY keyboard		Standard QWERTY keyboard	Standard 87 button QWERTY keyboard	Standard 88 button QWERTY keyboard
Pointing Device	Touchpad with 2 button control		Stylus to be used with the touch screen, and a touchpad with 3 button control	Stylus to be used with touch screen, and a touchpad with 2 button control	Pointing device (joystick)
CPU	Mobile Pentium III		850MHz Intel Celeron	800MHz Intel Pentium III	600MHz Intel Pentium III
Memory	128MB-512MB DRAM		128 MB-512 MB RAM	256MB-512MB SDRAM	128MB-512MB DRAM
Storage	10GB Min Hard Drive		20 or 30 GB Hard Drive	30 GB Hard Drive	5GB or higher
Dimension	12.2 in (W) x 10 in (L) x 3.5 in (H)		(L) 12in x (W) 9.8in x (D) 2.2in	2.3in (H) x 9.5in (D) x 11.8in (W)	12in. x 10in x 2.5in.
Weight			7.5 lbs (120oz)	9 lbs (144oz)	11lbs (176oz)
PC Cards and Expansion Slots	2 Type II/1 Type III PCMCIA slots		1 slot for Type I or Type II card, External Type III PC card support with optional adapter	1 Type II or Type III	2 Type I/II or 1 Type III PCMCIA ports
			Built in RJ-11 and RJ-45 jacks for integrated fax/modem and Ethernet		
			USB connector, 9 pin serial port, 15 pin external video CRT port		
Audio	Yes		Yes	Yes	
Display	13.3in. TFT - 1024x768		12.1 in TFT SVGA Outdoor	13in. 1024x768 (XGA)	12.1in. SVGA (800x600) Daylight

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Company	DOLCH	EDNA	Itronix	Panasonic	Paravant
	XGA		Color Vue display with Anti Glare and Touch screen	transmissive, anti-reflective TFT Active Matrix Color LCD with Touch screen	Readable Display
			2X AGP 3D Graphics Engine with motion compensation	or 12.1in. 800x600 (SVGA) transflective, daylight-readable TFT Active Matrix Color LCD with Touch screen	
			Support for 64 bit internal graphics acceleration with integrated 8MB SGRAM XGA through VGA port		
Ruggedization	Yes	Yes	26 repeated 3ft drops	Yes	Yes
Battery Life				4 hours with first battery and 10 hours with second battery	
RF Comm and	Combined 56 K Modem w/10/00 NIC		CDPD, Motient (ARDIS), GSM, Cingular (BSWD)	Integrated Wired LAN (10/100 Ethernet)	10/100 Ethernet Port
Other Communications				Integrated 802.11b Wireless LAN (Cisco Aironet, Lucent Orinoco)	
				Integrated Wireless Solutions (CDPD, DataTAC, Mobitex, GSM/GPRS, 1xRTT/CDMA)	
				Integrated Global Positioning System (GPS)	
Scanners	No		No	No	No

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Table IV. Handheld Computer Specifications

Company	Handheld Products	Intermec
Product	Dolphin 7400	700 Series Mobile Comp.
Product Type	Handheld	Handheld
Platform	MS Windows CE	MS Pocket PC 2002
Touch screen	Yes	Yes
Keyboard	On screen QWERTY keyboard and (35, 43, or 56 button) alphanumeric keypad	On screen QWERTY keyboard and 19 button alphanumeric keypad
Pointing Device	Stylus to be used with the touch screen	Stylus to be used with the touch screen
CPU	200MHz, Intel StrongArm RISC	206MHz, Intel StrongArm 1110 RISC
Memory	32MB RAM	64MB RAM
Storage	256MB with compact Flash card	32MB
Dimension	(L) 9.6in x (W) 3.45in x (D) 1.9in at display; (W)2.7in x (D)1.6in at grip	(H) 3.5 in, (W) 1.5 in., (L) 7.25in.
Weight	22.5 oz. (1.41lbs)	16 ounces (1lb)
PC Cards and Expansion Slots		
Audio	No	No
Display	3.8in 1/4 VGA (240 x 320 portrait mode)	Monochrome LCD, 3.8"
	EL backlit, touch screen option available	240x320 pixels, Electroluminescent backlight
		touch screen
Ruggedization	5ft drop	5ft drop
Battery Life		8-10 hours
RF Comm and	Optional Integrated 56k modem	RS232, IrDA 1.1 (115kbps),
Other Communications		10 Base-T Ethernet
		LAN: 802.11b (Wi-Fi certified)
		WAN: GSM/GPRS, CDPD, Data TAC, Mobitex
		Bluetooth compatible module
Scanners		Integrated linear or PDF417 laser scanner

Table V. Palm Computer Specifications

Company	Palm	Symbol
Product	M515	SPT 1800
Product Type	Handheld (Palm device)	Handheld (Palm device)
Platform	Palm OS v4.1	Palm OS
Touch screen	Yes	Yes
Keyboard	On screen QWERTY keyboard	On screen QWERTY keyboard
Pointing Device	Stylus to be used with the touch screen	Stylus to be used with the touch screen
CPU	Motorola Dragonball VZ 33MHz	Motorola Dragonball VZ 33MHz
Memory	16MB RAM	8MB RAM/ 4MB ROM 16MB RAM/4MB ROM (Batch version)
Storage		
Dimension	4.5 in x 3.1 in x .5 in	1 in. (H) x 3-5/8 in. W x 7 in. L
Weight	4.9 oz. (.3lbs)	Batch version: 10.6 oz/300 gm (.66lbs); Wireless version: 12.2 oz/346 gm (.76lbs)
PC Cards and Expansion Slots		
Audio	No	No
Display	TFT color screen with touch screen, 160x160 pixel display, 65,000 colors	High contrast, anti-reflective 160 x 160 monochrome LCD display, touch screen
Ruggedization	No	4ft drop
Battery Life		
RF Comm and	Requires an ISP account and data enabled phone or modem	Optional CDPD, GSM/GPRS, user accessible SIM socket for GSM/GPRS
Other Communications		Internal (WLAN), External (WWAN)
Scanners	No	Integrated miniature scan engine

Table VI. Alternative Computer Specifications

Company	LXE	Xplorer
Product	MX3	GeneSys Maximus
Product Type	Alternative device	Alternative device
Platform	ROM-DOS 6.22	MS Windows XP
Touch screen	Yes	Yes
Keyboard	Hard 63 button QWERTY keypad	On screen QWERTY keyboard
Pointing Device	Stylus to be used with the touch screen	Stylus to be used with the touch screen
CPU	Intel 486 SX ULP	500MHz Intel Pentium III
Memory	4MB Dynamic RAM, 8MB Compact Flash	8MB onboard video RAM
Storage		
Dimension	8in. x 6in. X1.35in.	
Weight	1.9 lbs (30.8oz)	
PC Cards and Expansion Slots	2 PCMCIA v. 2.1 slots, Left socket - Type I or II, Center socket - Type I, II or III	
Audio	No	No
Display	640 x 240 1/2 VGA LCD 16 grayscale, Transflective monochrome (indoor/outdoor), 6in. Viewing area, .22 dot pitch	12.1in. SVGA (800x600), Transflective, active matrix color LCD, touch screen
Ruggedization	4ft drops	
Battery Life	8 hours	6 hours
RF Comm and	24.GHz 802.11b Radios, Cisco Aironet, Agere Ornioco	Factory integrated WWAN CDPD, GSM (GPRS), GPS,
Other Communications		Factory integrated WLAN 802.11
		External options CDPD, GPS (GPRS), Tetra, Satellite
Scanners	Code 39, Interleaved 2 Of 5 Discrete 2 of 5 UPC-A, UPC-E, code 128, Plessey, Codabar	No

Appendix B. Data Collection Forms

IN-BRIEFING

AFRL is researching technologies that will assist in performing work at the Point of Maintenance (POMx). These technologies will include capabilities to display technical data, open and close work orders, and order parts. Several mobile computing devices will be used to provide the access needed to complete your maintenance jobs.

Objective:
The objective of this evaluation focuses on rating the effectiveness of several hardware devices for viewing CAMS forms on the flight line.

Hardware:
- Panasonic Toughbook Computer
- Paravant Scorpion Computer
- Itronix GoBook Computer
- Dolch Computer System
- EDNA Computer
- Intermec 700 Series Handheld Computer
- Dolphin 7400 Handheld Computer
- LXE Computer
- Xplorer Slate Computer
- Symbol Palm
- Palm 515

Scenario:
As you are using each device, imagine that you are using it on the flight line to open a work order, order a part, or close a work order. Please respond to questions with this idea in mind.

Task:
There are a total of four stations we would like you to visit. Your clipboard will have the order in which you are to visit the device stations in the upper right hand corner. When you reach the device station, you will be asked to perform a common task.

After using all of the devices you can fill out the questionnaires attached to each clipboard. These questionnaires will help us obtain your overall impressions and feedback about the strengths and weaknesses of the devices you viewed and evaluated today.

CONSENT FORM
NEW TECHNOLOGIES FOR MAINTENANCE AND LOGISTICS INFORMATION SYSTEM STUDIES

1. Nature and Purpose: I have been asked to volunteer to act as a subject in the research project named above. The purpose of this effort is to examine screen readability, hardware packaging, and keyboard use of the following devices: the laptops, Panasonic Toughbook, the Paravant computer, the ITRONIX GoBook, Dolch computer, and the EDNA computer. The handheld computers Dolphin 7400, and Intermec 700. Slate and LXE computers include the LXE and Xplorer. Finally, handheld computers include the Symbol, and Palm 515. This usability test will consists of observations of task performance, and a feedback questionnaire about the usability of the device(s). The time requirement is for the evaluation of all devices will not exceed 6 hours. This research will be conducted in the maintenance and logistics facilities at Nellis AFB. Specific sites will be identified by the supporting commands involved. There will be approximately 12 subjects in this research effort.

2. Experimental Procedures: The participant will interact with each of the devices to determine their usability. Participants will be required to don chemical resistant gloves during a portion of the task. After each portion of the task, the participant will fill out a post-condition questionnaire. When both portions are completed, the participant will fill out a posttest questionnaire.

3. Discomfort and Risks: My participation will not involve risks greater than I encounter performing my normal duties.

4. Precautions for Female Subjects: None.

5. Benefits: I will not receive any known medical benefits resulting from participation in this experiment.

My participation in this study will help to ensure that the application and further development of these technologies are designed to meet my needs. The ultimate benefit of this project will be to make maintenance and logistics personnel more effective and make their jobs easier. The only other way to obtain the required information would be to conduct studies in a laboratory setting using non-maintenance personnel. These people would not be representative of maintenance personnel, and the information gathered would not reflect the true needs of maintenance personnel. I am encouraged to provide the experimenter with feedback about the experiment so that my concerns can be considered in future investigations.

6. Alternative: Choosing not to participate in this study is your alternative to volunteering for the study.

7. Entitlements and Confidentiality:

      a. Records of my participation in this study may only be disclosed according to federal law, including the Federal Privacy Act, 5 U.S.C. 552a, and its implementing regulations.

b. I understand my entitlements to medical and dental care and/or compensation in the event of injury are governed by federal laws and regulations, and that if I desire further information I may contact the administrator of the medical treatment facility at 99th MSS/SGST, (702) 653-2778.

c. If an unanticipated event (medical misadventure) occurs during my participation in this study, I will be informed. If I am not competent at the time to understand the nature of the event, such information will be brought to the attention of my next of kin.

d. The decision to participate in this research is completely voluntary on my part. No one has coerced or intimidated me into participating in this program. I am participating because I want to. Captain Matthew Goddard, AFRL/HESR, DSN 986-4401 or his representative has adequately answered any and all questions I have about this study, my participation, and the procedures involved. I understand that Captain Goddard or his representative will be available to answer any questions concerning procedure throughout this study. I understand that if significant new findings develop during the course of this research, which may relate to my decision to continue participation, I will be informed. I further understand that I may withdraw this consent at any time and discontinue further participation in this study without prejudice to my entitlements. I also understand that the medical monitor of this study may terminate my participation in this study if she or he feels this to be in my best interest.

_____   _____
VOLUNTEER SIGNATURE   DATE

_____   _____
INVESTIGATOR SIGNATURE   DATE

_____   _____
WITNESS SIGNATURE   DATE

PRIVACY ACT STATEMENT

Authority: We are requesting disclosure of personal information, to include your Social Security Number. Researchers are authorized to collect personal information (including social security numbers) on research subjects under The Privacy Act-5 USC 552a, 10 USC 55, 10 USC 8013, 32 CFR 219, 45 CFR Part 46, and EO 9397, November 1943 (SSN).

Purpose: It is possible that latent risks or injuries inherent in this experiment will not be discovered until some time in the future. The purpose of collecting this information is to aid researchers in locating you at a future date if further disclosures are appropriate.

Routine Uses: Information (including name and SSN) may be furnished to Federal, State and local agencies for any uses published by the Air Force in the Federal Register, 52 FR 16431, to include, furtherance of the research involved with this study and to provide medical care.

Disclosure: Disclosure of the requested information is voluntary.   No adverse action whatsoever will be taken against you, and no privilege will be denied you based on the fact you do not disclose this information. However, your participation in this study may be impacted by a refusal to provide this information.

ICD Distribution: Original filed with protocol records by PI; copy 1, subject; copy 2, subject's medical record (if more than minimal risk protocol.)

Pre-Test Questionnaire

Last Name: _____

First Name: _____   Middle Initial: _____   Rank: _____

Squadron: _____   AFSC: _____

Time in AF (in years) _____   Time in ACC (in years) _____

Current Aircraft _____   Time on current aircraft (in years) _____

Other weapon systems worked: _____

Current job title: _____   Years experience at current job: _____

Previous jobs held: _____   Years experience at previous jobs: _____

How often do you use CAMS?

What actions do you take in a typical CAMS session? e.g., (open wo, close wo, order parts)

How long does a typical CAMS session last?

When do you have to immediately access CAMS?

What types of activities can wait until the end of your shift until they are entered in CAMS?

Itronix GoBook Laptop Computer
POST-CONDITION QUESTIONNAIRE

Subject Number: ___/___/___
Date: ___/___/___
Sequence Order: ___/___/___

All information will remain confidential.
Please put one check mark per statement:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable
Section 1 (Hardware)					
The size of the display was:					
The size of the computer was:					
The apparent ruggedization of the device was:					
The layout of the keyboard was:					
Ease in using the pointing device was:					
Section 2 (Software)					
Navigating through the program was:					
Ease in entering data into the device was:					
The use of drop down menus was:					
Section 3 (Environment)					
Ease in reading data while the device was in direct sunlight was:					
The perceived portability of the device was:					

Comments:

Feature most liked: _____
Feature least liked: _____

72

Panasonic ToughBook Laptop Computer
POST-CONDITION QUESTIONNAIRE

Sequence Order: ___ ___ ___ ___ ___ ___

All information will remain confidential.
Please put one check mark per statement:

Comments:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable
Section 1 (Hardware)					
The size of the display was:					
The size of the computer was:					
The apparent ruggedization of the device was:					
The layout of the keyboard was:					
Ease in using the pointing device was:					
Section 2 (Software)					
Navigating through the program was:					
Ease in entering data into the device was:					
The use of drop down menus was:					
Section 3 (Environment)					
Ease in reading data while the device was in direct sunlight was:					
The perceived portability of the device was:					

Feature most liked: _____

Feature least liked: _____

Dolch Laptop Computer
POST-CONDITION QUESTIONNAIRE

All information will remain confidential.
Please put one check mark per statement:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable
Section 1 (Hardware)					
The size of the **display** was:					
The size of the **computer** was:					
The apparent **ruggedization** of the device was:					
The layout of the **keyboard** was:					
Ease in using the **pointing device** was:					
Section 2 (Software)					
Navigating through the program was:					
Ease in **entering data** into the device was:					
The use of **drop down menus** was:					
Section 3 (Environment)					
Ease in **reading data** while the device was in direct sunlight was:					
The perceived **portability** of the device was:					

Comments:

Feature most liked: _____
Feature least liked: _____

74

Paravant Laptop Computer
POST-CONDITION QUESTIONNAIRE

Subject Number: ___/___/
Date: ___/___/___

Sequence Order: ___ ___ ___ ___ ___

All information will remain confidential.
Please put one check mark per statement:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable	Comments:
Section 1 (Hardware)						
The size of the display was:						
The size of the computer was:						
The apparent ruggedization of the device was:						
The layout of the keyboard was:						
Ease in using the pointing device was:						
Section 2 (Software)						
Navigating through the program was:						
Ease in entering data into the device was:						
The use of drop down menus was:						
Section 3 (Environment)						
Ease in reading data while the device was in direct sunlight was:						
The perceived portability of the device was:						

Feature most liked: _____
Feature least liked: _____

75

EDNA Computer
POST-CONDITION QUESTIONNAIRE

Subject Number: _____
Date: ___ / ___ / ___

Sequence Order: ___ ___ ___

All information will remain confidential.
Please put one check mark per statement:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable	Comments:
Section 1 (Hardware)						
The size of the display was:						
The size of the **computer** was:						
The **apparent ruggedization** of the device was:						
The **layout of the keyboard** was:						
Ease in using the **pointing device** was:						
Section 2 (Software)						
Navigating through the program was:						
Ease in entering data into the device was:						
The use of **drop down menus** was:						
Section 3 (Environment)						
Ease in **reading data while the device was in direct sunlight** was:						
The **perceived portability** of the device was:						

Feature most liked: _____
Feature least liked: _____

76

LXE Computer
POST-CONDITION QUESTIONNAIRE

Subject Number: _____
Date: ___ / ___ / ___

Sequence Order: ___ ___ ___

All information will remain confidential.
Please put one check mark per statement.

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable	Comments:
Section 1 (Hardware)						
The size of the display was:						
The size of the **computer** was:						
The **apparent ruggedization of the device** was:						
The **layout of the keyboard** was:						
Ease in using the **pointing device** was:						
Section 2 (Software)						
Navigating through the program was:						
Ease in **entering data** into the device was:						
The use of **drop down menus** was:						
Section 3 (Environment)						
Ease in **reading data** while the device was **in direct sunlight** was:						
The **perceived portability** of the device was:						

Feature most liked: _____

Feature least liked: _____

Xplorer Slate Computer
POST-CONDITION QUESTIONNAIRE

Please put one check mark per statement:

Subject Number: _____ / _____
Date: _____ / _____ / _____

Sequence Order: _____ — _____ — _____

Comments:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable
Section 1 (Hardware)					
The size of the **display** was:					
The size of the **computer** was:					
The **apparent ruggedization** of the device was:					
The layout of the **keyboard** was:					
Ease in using the **pointing device** was:					
Section 2 (Software)					
Navigating through the program was:					
Ease in **entering data** into the device was:					
The use of **drop down menus** was:					
Section 3 (Environment)					
Ease in reading data while the device was in **direct sunlight** was:					
The perceived **portability** of the device was:					

Feature most liked: _____

Feature least liked: _____

Intermec 710 Handheld Computer
POST-CONDITION QUESTIONNAIRE

Subject Number: ___/___
Date: ___/___/___

Sequence Order: ___

All information will remain confidential.
Please put one check mark per statement:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable
Section 1 (Hardware)					
The size of the display was:					
The size of the **computer** was:					
The **apparent ruggedization** of the device was:					
The **layout of the keyboard** was:					
Ease in using the **pointing device** was:					
Section 2 (Software)					
Navigating through the program was:					
Ease in **entering data** into the device was:					
The use of **drop down menus** was:					
Section 3 (Environment)					
Ease in **reading data** while the device was in direct sunlight was:					
The **perceived portability** of the device was:					

Comments:

Feature most liked: _____
Feature least liked: _____

79

Dolphin 7400 Handheld Computer
POST-CONDITION QUESTIONNAIRE

Subject Number: ___/___/
Date: ___/___/___

Sequence Order: ___/___/___

All information will remain confidential.
Please put one check mark per statement:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable	Comments:
Section 1 (Hardware)						
The size of the display was:						
The size of the **computer** was:						
The **apparent ruggedization** of the device was:						
The **layout of the keyboard** was:						
Ease in using the **pointing device** was:						
Section 2 (Software)						
Navigating through the program was:						
Ease in entering data into the device was:						
The use of **drop down menus** was:						
Section 3 (Environment)						
Ease in reading data while the device was in direct sunlight was:						
The **perceived portability** of the device was:						

Feature most liked: _____
Feature least liked: _____

80

Symbol Palm Computer
POST-CONDITION QUESTIONNAIRE

Sequence Order: ___ ___ ___

All information will remain confidential.
Please put one check mark per statement:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable
Section 1 (Hardware)					
The size of the **display** was:					
The size of the **computer** was:					
The apparent **ruggedization** of the device was:					
The **layout of the keyboard** was:					
Ease in using the **pointing device** was:					
Section 2 (Software)					
Navigating through the program was:					
Ease in **entering data** into the device was:					
The use of **drop down menus** was:					
Section 3 (Environment)					
Ease in **reading data while the device was in direct sunlight** was:					
The **perceived portability** of the device was:					

Comments:

Feature most liked: _____
Feature least liked: _____

81

Palm 515 Palm Computer
POST-CONDITION QUESTIONNAIRE

Subject Number: __/__/__
Date: __/__/__
Sequence Order: __/__/__/__

All information will remain confidential.
Please put one check mark per statement:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable
Section 1 (Hardware)					
The size of the display was:					
The size of the computer was:					
The apparent ruggedization of the device was:					
The layout of the keyboard was:					
Ease in using the pointing device was:					
Section 2 (Software)					
Navigating through the program was:					
Ease in entering data into the device was:					
The use of drop down menus was:					
Section 3 (Environment)					
Ease in reading data while the device was in direct sunlight was:					
The perceived portability of the device was:					

Comments:

Feature most liked: _____
Feature least liked: _____

82

Panasonic ToughBook Laptop Computer
POST-CHEMGEAR CONDITION QUESTIONNAIRE

Subject Number: ___/___

Date: ___ / ___ / ___

Sequence Order: ___ ___ ___

All information will remain confidential.
Please put one check mark per statement:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable	Comments:
Section 1 (Hardware) While using chemical gear, ease in using **the pointing device was:**						
Section 2 (Software) While using chemical gear, ease in **entering data into the device was:**						
Section 3 (Environment) While using chemical gear, ease in **reading data while the device was in direct sunlight was:**						
While using chemical gear, the **perceived portability** of the device was:						

Feature most liked: _____

Feature least liked: _____

83

Paravant Laptop Computer
POST-CHEMGEAR CONDITION QUESTIONNAIRE

Subject Number: ___/___/___
Date: ___/___/___

Sequence Order: ___ ___ ___ ___ ___

All information will remain confidential.
Please put one check mark per statement:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable	Comments:
Section 1 (Hardware) — While using chemical gear, ease in using **the pointing device was:**						
Section 2 (Software) — While using chemical gear, ease in **entering data into the device was:**						
Section 3 (Environment) — While using chemical gear, ease in **reading data while the device was in direct sunlight was:**						
While using chemical gear, the **perceived portability** of the device was:						

Feature most liked: _____

Feature least liked: _____

84

Itronic GoBook Laptop Computer
POST-CHEMGEAR CONDITION QUESTIONNAIRE

Subject Number: ___/___/___
Date: ___/___/___

Sequence Order: ___/___/___

All information will remain confidential.
Please put one check mark per statement:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable	Comments:
Section 1 (Hardware) While using chemical gear, ease in using **the pointing device was:**						
Section 2 (Software) While using chemical gear, ease in **entering data into the device was:**						
Section 3 (Environment) While using chemical gear, ease in **reading data while the device was in direct sunlight was:**						
While using chemical gear, the **perceived portability** of the device was:						

Feature most liked: _____

Feature least liked: _____

85

Dolch Laptop Computer
POST-CHEMGEAR CONDITION QUESTIONNAIRE

Sequence Order: __ __ __

All information will remain confidential.
Please put one check mark per statement:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable	Comments:
Section 1 (Hardware) While using chemical gear, ease in using **the pointing device** was:						
Section 2 (Software) While using chemical gear, ease in **entering data into the device** was:						
Section 3 (Environment) While using chemical gear, ease in **reading data while the device was in direct sunlight** was:						
While using chemical gear, **the perceived portability** of the device was:						

Feature most liked: _____

Feature least liked: _____

EDNA Computer
POST-CHEMGEAR CONDITION QUESTIONNAIRE

Subject Number: ___
Date: ___ / ___ / ___

Sequence Order: ___ ___ ___ ___

All information will remain confidential.
Please put one check mark per statement:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable	Comments:
Section 1 (Hardware) While using chemical gear, ease in using **the pointing device was:**						
Section 2 (Software) While using chemical gear, ease in **entering data into the device was:**						
Section 3 (Environment) While using chemical gear, ease in **reading data while the device was in direct sunlight was:**						
While using chemical gear, the **perceived portability of the device was:**						

Feature most liked: _____

Feature least liked: _____

Dolphin 7400 Handheld Computer
POST-CHEMGEAR CONDITION QUESTIONNAIRE

All information will remain confidential.
Please put one check mark per statement:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable	Comments:
Section 1 (Hardware) While using chemical gear, ease in using **the pointing device** was:						
Section 2 (Software) While using chemical gear, ease in **entering data into the device** was:						
Section 3 (Environment) While using chemical gear, ease in **reading data while the device was in direct sunlight** was:						
While using chemical gear, the **perceived portability** of the device was:						

Feature most liked: _____

Feature least liked: _____

Intermec 710 Handheld Computer
POST-CHEMGEAR CONDITION QUESTIONNAIRE

Subject Number: _____
Date: ___ / ___ / ___

Sequence Order: _____

All information will remain confidential.
Please put one check mark per statement:

		Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable	Comments:
Section 1 (Hardware)	While using chemical gear, ease in using the pointing device was:						
Section 2 (Software)	While using chemical gear, ease in entering data into the device was:						
Section 3 (Environment)	While using chemical gear, ease in reading data while the device was in direct sunlight was:						
	While using chemical gear, the perceived portability of the device was:						

Feature most liked: _____

Feature least liked: _____

89

LXE Computer

POST-CHEMGEAR CONDITION QUESTIONNAIRE

Subject Number: _____

Date: ___ / ___ / ___

Sequence Order: ___ ___ ___

All information will remain confidential.
Please put one check mark per statement:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable	Comments:
Section 1 (Hardware) While using chemical gear, ease in using the **pointing device** was:						
Section 2 (Software) While using chemical gear, ease in **entering data** into the device was:						
Section 3 (Environment) While using chemical gear, ease in **reading data while the device was in direct sunlight** was:						
While using chemical gear, the **perceived portability** of the device was:						

Feature most liked: _____

Feature least liked: _____

90

Xplorer Slate Computer
POST-CHEMGEAR CONDITION QUESTIONNAIRE

Subject Number: _____

Date: ___/___/___

Sequence Order: ___ ___ ___

All information will remain confidential.
Please put one check mark per statement:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable	Comments:
Section 1 (Hardware) While using chemical gear, ease in using **the pointing device was:**						
Section 2 (Software) While using chemical gear, ease in **entering data into the device was:**						
Section 3 (Environment) While using chemical gear, ease in **reading data while the device was in direct sunlight was:**						
While using chemical gear, **the perceived portability** of the device was:						

Feature most liked: _____

Feature least liked: _____

Symbol Palm Computer
POST-CHEMGEAR CONDITION QUESTIONNAIRE

Subject Number: _____
Date: ___/___/___

Sequence Order: ___ ___ ___

All information will remain confidential.
Please put one check mark per statement:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable	Comments:
Section 1 (Hardware) While using chemical gear, ease in using **the pointing device was:**						
Section 2 (Software) While using chemical gear, ease in **entering data into the device was:**						
Section 3 (Environment) While using chemical gear, ease in **reading data while the device was in direct sunlight was:**						
While using chemical gear, the **perceived portability of the device was:**						

Feature most liked: _____

Feature least liked: _____

92

Palm 515 Palm Computer
POST-CHEMGEAR CONDITION QUESTIONNAIRE

Subject Number: ___

Date: __ / __ / __

Sequence Order: ___

All information will remain confidential.
Please put one check mark per statement:

	Completely acceptable	Reasonably acceptable	Borderline	Moderately unacceptable	Extremely unacceptable	Comments:
Section 1 (Hardware) While using chemical gear, ease in using **the pointing device** was:						
Section 2 (Software) While using chemical gear, ease in **entering data into the device** was:						
Section 3 (Environment) While using chemical gear, ease in **reading data while the device was in direct sunlight** was:						
While using chemical gear, the perceived **portability** of the device was:						

Feature most liked: _____

Feature least liked: _____

93

LAPTOP POST-TEST QUESTIONNAIRE

All information will remain confidential.
This is not a rating form, please "RANK ORDER" the devices according to your preference!
Fill in the order of preference in the table provided. (1 = most preferred, 4 = lease preferred)

	A. Panasonic Toughbook 34 Laptop Computer	B. Paravant Laptop Computer	C. Itronix Gobook Laptop Computer	D. Dolch Laptop Computer	E. EDNA Computer
Rank your **overall preference** for a device.					
Rank your preference when **viewing the screen under direct sunlight.**					
Rank your preference for a device when **entering numeric data.**					
Rank your preference for a device when **entering alphabetic data.**					
Rank your preference for a device when **considering the perceived portability.**					
Rank your preference for a device when **considering the apparent ruggedization.**					

Please include any comments or recommendations: _____

94

HANDHELD POST-TEST QUESTIONNAIRE

All information will remain confidential.
This is not a rating form, please "RANK ORDER" the devices according to your preference!
Fill in the order of preference in the table provided. (1 = most preferred, 3 = lease preferred)

	A. Dolphin 7400 Handheld Computer	C. Intermec 700 Series Handheld Computer
Rank your overall preference for a device.		
Rank your preference when viewing the screen under direct sunlight.		
Rank your preference for a device when entering numeric data.		
Rank your preference for a device when entering alphabetic data.		
Rank your preference for a device when considering the perceived portability.		
Rank your preference for a device when considering the apparent ruggedization.		

Please include any comments or recommendations: _____

95

SLATE AND LXE POST-TEST QUESTIONNAIRE

Subject Number: ___ / ___ / ___

Date: ___ - ___ - ___

Sequence Order: _____

All information will remain confidential.
This is not a rating form, please **"RANK ORDER"** the devices according to your preference!
Fill in the order of preference in the table provided. (1 = most preferred, 2 = lease preferred)

	A. LXE Computer	B. Xplorer Slate Computer
Rank your **overall preference for a device.**		
Rank your preference when **viewing the screen under direct sunlight.**		
Rank your preference for a device when **entering numeric data.**		
Rank your preference for a device when **entering alphabetic data.**		
Rank your preference for a device when **considering the perceived portability.**		
Rank your preference for a device when **considering the apparent ruggedization.**		

Please include any comments or recommendations: _____

96

PALM POST-TEST QUESTIONNAIRE

Subject Number:

Date: ___/___/___

Sequence Order: ___

All information will remain confidential.
This is not a rating form, please "**RANK ORDER**" the devices according to your preference!
Fill in the order of preference in the table provided. (1 = most preferred, 2 = lease preferred)

	A. Symbol Palm Computer	B. Palm 515 Palm Computer
Rank your **overall preference** for a device.		
Rank your preference when **viewing the screen under direct sunlight.**		
Rank your preference for a device when **entering numeric data.**		
Rank your preference for a device when **entering alphabetic data.**		
Rank your preference for a device when **considering the perceived portability.**		
Rank your preference for a device when **considering the apparent ruggedization.**		

Please include any comments or recommendations: _____

LAPTOP CHEM GEAR POST-TEST QUESTIONNAIRE

All information will remain confidential.

This is not a rating form, please **"RANK ORDER"** the devices according to your preference!

Fill in the order of preference in the table provided. (1 = most preferred, 4 = lease preferred)

	A. Panasonic Toughbook 34 Laptop Computer	B. Paravant Laptop Computer	C. Itronix Gobook Laptop Computer	D. Dolch Laptop Computer	E. EDNA Computer
Rank your **overall preference** for a device when wearing chemical gear.					
Rank your preference when viewing the screen **under direct sunlight** when wearing chemical gear.					
Rank your preference for a device when **entering numeric data** when wearing chemical gear.					
Rank your preference for a device when **entering alphabetic data** when wearing chemical gear.					
Rank your preference for a device when **considering the perceived portability** when wearing chemical gear.					
Rank your preference for a device when **considering the apparent ruggedization** when wearing chemical gear.					

Please include any comments or recommendations: _____

HANDHELD CHEM GEAR POST-TEST QUESTIONNAIRE

All information will remain confidential.
This is not a rating form, please "**RANK ORDER**" the devices according to your preference!
Fill in the order of preference in the table provided. (1 = most preferred, 3 = lease preferred)

	A. Dolphin 7400 Handheld Computer	C. Intermec 700 Series Handheld Computer
Rank your **overall preference for a** device when wearing chemical gear.		
Rank your preference when viewing the screen **under direct sunlight** when wearing chemical gear.		
Rank your preference for a device when **entering numeric data** when wearing chemical gear.		
Rank your preference for a device when **entering alphabetic data** when wearing chemical gear.		
Rank your preference for a device when **considering the perceived portability** when wearing chemical gear.		
Rank your preference for a device when considering the **apparent ruggedization** when wearing chemical gear.		

Please include any comments or recommendations: _____

SLATE AND LXE CHEM GEAR POST-TEST QUESTIONNAIRE

All information will remain confidential.
This is not a rating form, please **"RANK ORDER"** the devices according to your preference!
Fill in the order of preference in the table provided. (1 = most preferred, 2 = lease preferred)

	A. LXE Computer	B. Xplorer Slate Computer
Rank your **overall preference** for a device when wearing chemical gear.		
Rank your preference when **viewing the screen under direct sunlight** when wearing chemical gear.		
Rank your preference for a device when **entering numeric data** when wearing chemical gear.		
Rank your preference for a device when **entering alphabetic data** when wearing chemical gear.		
Rank your preference for a device when **considering the perceived portability** when wearing chemical gear.		
Rank your preference for a device when considering the **apparent ruggedization** when wearing chemical gear.		

Please include any comments or recommendations: _____

PALM CHEM GEAR POST-TEST QUESTIONNAIRE

Subject Number: _____

Date: ___ / ___ / ___

Sequence Order: ___

All information will remain confidential.

This is not a rating form, please "**RANK ORDER**" the devices according to your preference!

Fill in the order of preference in the table provided. (1 = most preferred, 2 = lease preferred)

	A. Symbol Palm Computer	B. Palm 515 Palm Computer
Rank your **overall preference** for a device when wearing chemical gear.		
Rank your preference when viewing the screen **under direct sunlight** when wearing chemical gear.		
Rank your preference for a device when **entering numeric data** when wearing chemical gear.		
Rank your preference for a device when **entering alphabetic data** when wearing chemical gear.		
Rank your preference for a device when **considering the perceived portability** when wearing chemical gear.		
Rank your preference for a device when considering the **apparent ruggedization** when wearing chemical gear.		

Please include any comments or recommendations: _____

101

Appendix C: Nellis Informal Heat and Sunlight Evaluation

August 2002

1 Introduction

The Air Force Directorate of Maintenance (USAF/ILM) and the Standard Systems Group, Maintenance Systems Division (HQ SSG/ILM) sponsored an evaluation of eleven potential electronic devices or "E-Tools" for flightline use. The primary purpose of this E-Tool Ruggedized Operational Device Evaluation and Observation (RODEO) was to examine hardware packaging, software user interface, and environmental factors associated with the usability of several potential Point of Maintenance (POMX) E-Tools for maintenance data collection on the flightline. AFRL/HESR and the University of Dayton Research Institute (UDRI) were commissioned by SSG/ILM to independently and objectively perform the evaluation. The evaluation was conducted at the 57th AGS, Nellis AFB, Nevada, 20-22 August 2002.

While the primary purpose of this effort was to evaluate maintainer feedback on usability of the equipment, many vendors and other government representatives were interested in determining the durability of the hardware in extreme heat and direct sunlight. Hardware is normally tested using rigorous procedures whereby numerous units of the same type are tested under very controlled settings. In this way, problems unique to one unit do not adversely affect the results associated with that hardware type (the results are averaged over all the units of the same type). Participants at Nellis, however, were interested in an informal evaluation of the devices and were willing to compromise testing rigor for the opportunities presented by the circumstances and conditions at Nellis in August. That is, many device types were available to test at once, heat and sunlight were conducive to testing, and the facilities were already available (due to the usability test underway). Given their knowledge of testing procedures, AFRL/HESR and UDRI were asked to conduct the informal heat and sunlight evaluation. The results of this evaluation are provided in this document.

2 Method

All vendors who provided hardware for the usability test were approached to determine whether they were interested in participating in the heat and sunlight test. The limitations of the testing procedure were explained to all potential participants (e.g., the fact that only one unit would be used instead of multiple units, therefore, potentially rendering results unique to the one unit that are not representative of the type of hardware as a whole). Participation was completely voluntary. If vendors for the hardware were unavailable to give permission for that device to be included in the test, the hardware was excluded from the test.

Hardware assessed in the informal heat and sunlight testing included the following items:

- Dolch, NotePAC Plus
- EDNA
- Itronix, GoBook
- LXE, MX3
- Panasonic, Toughbook 28

Prior to initiating the informal heat and sunlight evaluation, all of the devices were used in the usability test. At the beginning of the day all batteries were all fully charged; however, it should be noted that the heat endured and battery drain encountered during the usability test might have influenced the device performance results of the heat and sunlight evaluation. During the usability test, units were primarily kept in the shade where temperatures were approximately 100°F. However, all units were also periodically taken into the sun, whereby temperatures increased to approximately 115°F. After usability testing was complete, unit batteries were charged to attempt to rejuvenate the battery life prior to the heat and sunlight evaluation.

A table was set up in the sunlight and was repositioned throughout the testing period so that the hardware devices were always in direct sunlight. Devices were arranged side-by-side on the table and screens were tilted up toward the sun. A piece of paper was taped over the right half of the screen on each device so as to subjectively evaluate the degree of visual display degradation throughout the test.

The test lasted for a two-hour period. Observations of ambient temperature and ambient humidity were taken approximately every 15 minutes for the entire two-hour period. Measurement of screen temperature and display degradation began after one hour of testing. These measurements were also noted every 15 minutes for the final hour. Display degradation was determined by lifting the paper (without exposing the covered side to the sun) and subjectively comparing screen resolution and readability on either side of the paper. Observations were recorded for each device.

3 Results

Ambient temperatures averaged 113°F for the two-hour period, and ambient humidity averaged 12% for the same period. After the first hour of testing, observations of screen temperatures and display degradation were recorded every 15 minutes. Screen temperatures are depicted in Figure 1.
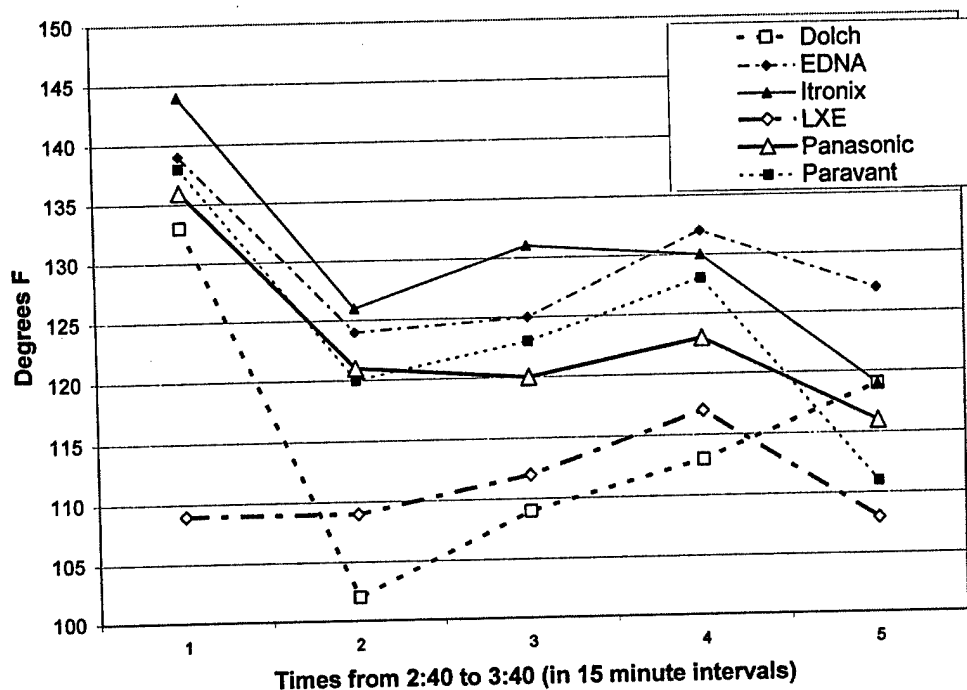
Screen Temperatures

Figure 1. Screen Temperatures

Observations of display degradation were also recorded during the second hour of the testing period. Results of these observations are shown in Table I.

Table I. Screen Degradation Results

Time	Dolch	EDNA	Itronix	LXE	Panasonic	Paravant
2:40	Some flowering on the half of the display exposed to sunlight	None	None	Some minor darkening	None	Some minor darkening
2:55	Entire display blacked out	None	None	Some minor darkening	None	None
3:10	Entire display blacked out	None	None	Some minor darkening	None	None
3:25	Entire display blacked out	None	None	Some minor darkening	None	None
3:40	Entire display blacked out	None	None	Some minor darkening	None	None

4   Discussion and Conclusions

Results from this informal evaluation of the effect of heat and sunlight on the six devices indicate that four of the six devices withstood the evaluation conditions without any noticeable change. Of these four, the Panasonic, Paravant, and Itronix devices withstood the evaluation without any difficulties.

While there was no observed degradation of the EDNA display during the heat and sunlight evaluation, results from the usability test had already indicated difficulties viewing the display. This test indicated users had problems discerning the contents of items on the screen not only while wearing chemical gear, but also when not wearing chemical gear (i.e., masks). Therefore, while there was no observed degradation in the heat and sunlight evaluation, users had previously determined that the screen was not readable in sunlight—regardless of extensive exposure to temperature and sunlight.

The LXE, MX3 device showed some minor darkening; however screen contents were still somewhat identifiable. This darkening effect may have been due to the nature of the screen type: it was the only passive matrix LCD screen included in the test. Again, as suggested by the results of the usability test, users also had problems reading the contents of the LXE screen while wearing chemical gear and while not wearing chemical gear (i.e., masks). Therefore, while the screen only darkened slightly in the heat and sunlight evaluation, users had previously determined that the screen was not readable in sunlight—regardless of extensive exposure to temperature and sunlight.

The Dolch, NotePAC Plus was not able to withstand the heat and sunlight evaluation conditions. After one hour of testing the screen began to flower on the half of the screen not covered by paper. Within the next 15 minutes, the entire screen blacked out and subsequently the screen temperature dropped substantially (refer to Figure 1). The computer remained in this state for the remainder of the evaluation. It is important to note that while the Dolch computer used in this evaluation indicated problems with heat and sunlight exposure, these problems could have occurred due to several factors. These factors include, but are not limited to, the following possibilities: first, the device may not have been representative of the device population– that is, it may have had some unique problems that other devices of this type would not have exhibited in a similar test; second, the device battery may have been low due to usage during the usability test in the morning.

5   Recommendations

Given the results of this informal heat and sunlight evaluation and the results of the usability test conducted during this same time period, the following recommendations are provided:

- It is recommended that rigorous testing of the Dolch NotePAC Plus be conducted to assure that this type of computer will endure the temperature and sunlight conditions imposed by extensive use in Air Force flightline environments.

- In accordance with recommendations from the usability test, the EDNA computer had multiple actual problems and multiple potential problems. These problems and potential problems seem to make this device unacceptable without major redesign of the system.

- In accordance with recommendations from the usability test, the LXE device had one real problem along with several potential problems. Modifications to this device may make it suitable for flightline use, if care is given to usability concerns, such as screen readability.